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Proceedings: Using Seeds of Native Species on Rangelands

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Research Results

Effective implementation of emerging native seed policies requires consideration of genetic issues in selecting seed sources, an understanding of seed certification options, the ability to interpret seed quality tests, and development and use of seed and seeding technology for an increasing number of species, including rare plants. This symposium was designed to aid natural resource management specialists and those involved in biodiversity and restoration issues.

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Contents

Front cover: *Elymus elymoides* (Raf.) Swezey, bottlebrush squirreltail. Drawn by Lenora Oosterhuis, an emigrant from Holland, a forest ecologist, and a freelance biological artist living in Boise, ID.

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Using Native Seeds on Rangelands

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Abstract—Historical rangeland revegetation with exotic species served well the soil conservation and forage production goals of the time. Current emphasis on multiple use, biological diversity, and the conservation of biological resources requires more use of native species. Increased use of native species is dependent on progress in scientific, management, and practical areas to address soil stabilization, diversity, scale and frequency of disturbance, weed dominance, and adaptation issues. Successful revegetation projects will be developed from a specific knowledge of the biology of the species and the ecology of the sites involved.

In the past, species selection for rangeland revegetation has closely followed the objectives for revegetation. Exotic species were preferentially selected because they were considered to best meet production and soil conservation objectives. Today's increased desire to use native species in revegetation sometimes follows the increasing emphasis on conservation goals for rangelands. But opinions are often strong and uncompromising on whether to use exotics or natives. This polarity has even been referred to as the "new range war" (Gutknecht 1992). Although land management and revegetation practices that support the transition from production to ecological goals, such as increasing biodiversity, are developing, those practices are constrained in a number of ways. Evaluation of past and current revegetation should be based on historical, economical, and environmental realities. We provide a brief historical perspective and discuss current issues affecting native seed use for rangeland revegetation to help clarify those issues.

Past and Current Seed Use

Emphasis on Exotic Species

Historically, the major driving forces for large scale rangeland revegetation have been watershed rehabilitation and forage production for livestock. For example, in Turkmenistan, strips of shrubs were seeded to provide more seasonally nutritional forage for sheep than was available from the dominant herbaceous vegetation (Nechaeva 1985). Likewise, various saltbushes (*Atriplex*) and other halophytes have been established on semiarid rangelands throughout the world to support livestock grazing (Le Houérou 1992; Squires and Ayoub 1992).

In the Western United States, devastating debris flows, gully erosion, and cattle die-offs before and after the turn of the 20th century signaled the need to manage and rehabilitate forest and rangeland watersheds (Roundy 1996). Although species from native ecosystems were tested in many early revegetation studies, they often failed because they were not adapted to the climate or site conditions, there was a lack of dependable precipitation and soil moisture to establish them, seeding techniques were inappropriate, or seeds were nonviable or nongerminable (Roundy and Biedenbender 1995; Roundy and Call 1988). Also hampering the use of native seeds was the difficulty in producing, harvesting, and sowing native seeds with appendages (Booth 1987). The urgency, costs, risks, and scale associated with rangeland rehabilitation led to the search for ideal species that would be widely adapted, easily produced and established, and grazing tolerant. When exotic grasses were found to fit these needs, large-scale rangeland revegetation became a reality. A limited number of exotic grass species that were widely adapted, including smooth brome (*Bromus inermis*) and orchard grass (*Dactylis glomerata*), were predominately seeded to stabilize mountain watersheds (Keck 1972; Meeuwig 1960; Monsen and McArthur 1995). Exotic wheatgrasses (*Agropyron* spp.) were seeded on thousands of acres of sagebrush (*Artemisia* spp.) rangelands (Johnson 1986). Lovegrasses (*Eragrostis* spp.) from South Africa and other warm-season exotic grasses were sown across Southwestern United States rangelands supported by summer rainfall (Roundy and Biedenbender 1995).

Revegetation projects conducted during the 1950's and 1960's using these exotic grasses can be judged as successful given the objectives of the time. Many of these projects continue to be highly productive for livestock and functional for soil conservation. Young and Evans (1986) estimated that crested wheatgrass (*Agropyron cristatum*, *A. desertorum*) seeded on 2 percent of the rangelands provides about 10 percent of the forage in Nevada. Native species, additional exotic introductions, as well as developed exotic plant materials and exotic-native crosses, still have high potential for traditional improvement of rangelands (Carlson and McArthur 1985; McArthur 1988). The comparatively high success of the exotic grasses during the past 50 years generally resulted in a lack of research, development, and use of native plant materials.

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Revegetation for Wildlife

An exception to the almost exclusive use of exotic species was the revegetation of rangelands for wildlife habitat improvement and for mineland reclamation. When mule deer (*Odocoileus hemionus*) populations in the West expanded between 1930 and the 1950's, maintenance of these populations to support hunting and its economic foundation for State game and fish departments became an important range management objective (Roundy 1996). At one time almost every Western State game and fish department was involved in some kind of revegetation research, often on bitterbrush (*Purshia tridentata*). Research in Utah, led by A. Perry Plummer, showed that native shrubs, forbs, and grasses could be successfully established in revegetation projects (McArthur 1992; Plummer and others 1968). Plummer's recognition of the ecotypic nature of many native plants and its importance in successful revegetation provided the foundation for research on genetics and ecology of shrubs and other native plants at the U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory in Provo, UT. Based on past and ongoing research, the Utah Division of Wildlife Resources has seeded over 400,000 acres for wildlife habitat improvement since 1958 using large amounts of native seed (Stevens 1996). The establishment of a seed warehouse has played a critical role in this effort by helping to encourage the market for a native seed industry, and then providing native seeds for numerous revegetation projects conducted by the Forest Service and U.S. Department of the Interior, Bureau of Land Management. It should be recognized that range revegetation for wildlife has often successfully involved the use of exotic legumes such as alfalfa (*Medicago sativa*) and sainfoin (*Onobrychis viciaefolia*), and the rosaceous forb, small burnet (*Sanguisorba minor*) (Stevens and others 1996; Yoakum and others 1980).

The future will see increased use of native species for wildlife habitat improvement because wildlife biologists currently consider habitat degradation and loss to be the most important issues threatening wildlife and fish (Flather and Hoekstra 1989). In Arizona, for example, appropriation of millions of dollars in State lottery monies to the Heritage Fund supports habitat acquisition and improvement. Utah's Habitat Authorization fee, assessed in conjunction with hunting and fishing licences, provides funds for wildlife habitat acquisition and enhancement. Wyoming's Habitat Trust Fund accomplishes a similar purpose.

Revegetation of Drastically Disturbed Lands

Although exotic species continue to be used in mineland reclamation, the use of native species has been encouraged by law. The Surface Mining Control and Reclamation Act of 1977, Public Law 95-87 (SMCRA), allows for the use of introduced species "...to achieve the approved postmining land use plan" (Sec 515. (b) (19)). However, as State and Federal regulatory agencies become increasingly concerned about biological diversity to support postmining land use, they are more frequently requiring "...a diverse, effective and permanent vegetative cover of the same seasonal variety native to the area of land..." (Sec 515. (b) (19)). This regulation and the greater expenditures in coal mine reclamation compared to rangeland rehabilitation to meet compliance and release the posted bond have been the major driving forces for developing a native plant industry (Roberts 1997). For example, in Wyoming 3,500 acres of mined lands were seeded to native species in 1994 (Luther 1995) and from 1981 through 1994, over 80 percent of the 360,000 lb of seed used in Wyoming's Abandoned Mineland Reclamation program has been native (Richmond 1995). Although only coal-mined land reclamation is covered by SMCRA, the law has had a major influence on reclamation of other mined lands. Kennecott Copper in Utah seeded over 1,200 acres to native plants in 1995 (Malin 1995).

The use of native species is currently emphasized for revegetation of other drastic disturbances such as roadsides, testing and drilling sites, abandoned farmlands, and linear corridors for gas and utility lines (Burke, this proceedings; Roundy and others 1995). Mitigation for threatened and endangered species whose habitat has been lost by road construction and other development has also encouraged the use of native species (Guerrant, this proceedings). This has been particularly emphasized in the State of California, which lists 200 threatened and endangered species. The California Department of Transportation has over 500 projects across roadsides in California using native species (Allen 1995). Over the last 5 years, the Wyoming Department of Transportation has used 274,000 lb of seed, of which 95 percent were native (Luther 1995). Currently, the U.S. Department of the Interior, National Park Service, road reconstruction program in eight Western parks will use more than 32,000 lb of native seeds on over 2,200 acres of roadsides (Beavers 1995).

Fire Rehabilitation

During the 1950's and 1960's, which Young and Evans (1986) called "the Golden Age of seeding crested wheatgrass," thousands of acres were seeded to exotic grasses to support livestock production (for example, see Heady and Bartolome 1977). There is little revegetation done today on public lands for that purpose. For example, the estimated average area the Bureau of Land Management in Utah treats annually by chaining is 4,900 acres, and for drill seeding only 50 acres (USDI, BLM 1991a). Because 86 percent of the livestock forage in the United States is produced on private lands (Gee and others 1992), revegetation to support animal production will continue to be important on such lands, and use of both exotic and native plants will continue. Grass, legume, and shrub mixtures to improve seasonal quality, including a number of salt, drought, and grazing tolerant exotic and native cultivars and hybrids, will support this use (Johnson and others 1981).

In contrast, fire rehabilitation is the overwhelming revegetation effort on public rangelands today. On Western rangelands, invasion by cheatgrass (*Bromus tectorum*) and other annual weeds has increased the frequency of fire, generated a fire-feedback loop that favors continued weed dominance, and destroyed perennial vegetation and resource values on millions of acres (McArthur and others 1990; Monsen and Kitchen 1994). The magnitude of this problem is currently

much greater than the efforts directed at its solution. The Bureau of Land Management's greenstripping program has been effective in creating in-place firebreaks to reduce fire and the spread of weeds, but its scale of application is much smaller than the area threatened (Pellant 1995). A Federal research program has been initiated to develop ways to restore the native diversity of affected rangelands (Pyke and Borman 1993). Numerous scientists are working on different aspects of rangeland weeds and revegetation (Monsen and Kitchen 1994), but the complexity and scale of the problem will require much more support and attention than is currently allocated. Consequently, the major approach of the Bureau of Land Management is to revegetate burned areas, mainly with proven and available exotic grasses (Richards and others, this proceedings). For example, after the unusually wet spring of 1995 produced extreme fuel loads of annual weeds, over 2 million acres of rangelands in the West burned in 1996 (Roberts 1997). The Bureau of Land Management is only reseeding 14 percent of these lands, but at a projected cost of over $21 million. In Utah alone, over 65 tons of seed were ordered for fire rehabilitation (Hindley 1997). In terms of spatial application, fire rehabilitation dwarfs the other uses of revegetation on rangelands. Supplies of native seeds are greatly exceeded by demand in high fire years (Johansen 1997).

Wetland Restoration and Rehabilitation

Although much smaller in area than uplands treated for fire rehabilitation, wetland revegetation is increasing in importance as wetlands become the focal point of many management areas (USDI, BLM 1991b). Major loss of wetlands throughout the United States (Swift 1984), and a recognition of their critical ecological and environmental values, are driving the emphasis on wetland rehabilitation, restoration, and creation (Mitsch and Gosselink 1993). The Clean Water Act of 1972 and Administrative Order 11990 mandating wetland mitigation for "no net loss" provides for Federal protection. Other acts and programs including the Food Security Act or "Swampbuster" Act, the Conservation Reserve Program, the Wetlands Reserve Program, and the North American Wetlands Conservation Act were designed to encourage restoration of these valuable systems (Mitsch and Gosselink 1993; White and others 1992). Appropriate use of revegetation to improve wetland systems involves understanding and treating the causes of degradation from a watershed perspective and implementing mitigation procedures that will encourage successful hydrologic function and vegetation establishment (Briggs 1996). Revegetation is required where a lack of residual plants or seed dispersal limit recovery.

Native wetland species should have the potential to handle revegetation needs without looking for exotic species as was done for upland rangelands. However, the dynamic spatial and temporal variability of resource availability within wetland systems creates a challenge for development of plant materials for revegetation (Hansen and others 1995; Manning and Padgett 1995). The numerous species that sort out over a short space require that we deal with a comparatively large number of species compared to upland sites. Many of these species survive the dynamics of wetland systems by propagating vegetatively. The result is that there is a need for seed or planting stock for hundreds of species. Information on germination and propagation techniques, as well as the environmental conditions that limit or enhance establishment and survival of wetland species, is especially needed to advance revegetation. The U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center in Aberdeen, ID, supports availability of widely adapted plant materials of common species considered high priority for planting projects (table 1) (Hoag 1997).

Approaches, Opportunities, and Dilemmas

Objectives for revegetation follow a philosophical vision of what the land should be. For an increasing number of individuals, restoration of a historical ecosystem, thought to have much better function and value than the current system, is the ideal. Others focus on opposition to certain revegetation practices such as the use of chemical or mechanical plant control, presumably because these are unnatural disturbances. Justification for revegetation objectives and practices may be based on opinion, research, experience, or a lack thereof. Revegetation objectives and practices must be grounded in ecological and economic realities or they will never be successfully implemented,

Table 1—Numbers of accessions and species of wetland and riparian plant materials undergoing testing at the Aberdeen, ID, and Los Lunas , NM, Plant Materials Centers of the Natural Resource Conservation Service (Englert and White 1997; Hoag 1997; USDA, Natural Resource Conservation Service, Los Lunas Plant Materials Center 1994).

	Aberdeen		Los Lunas	Formal and informal
	Species	Accessions	species	releases
Grasses	7	106		15
Grass-like species				1
Forbs				2
Shrubs	5	21	15	12
Willows/cottonwoods	14	121	15	19

especially on a large scale. In this regard, there are a number of real dilemmas, constraints, or opportunities to using native seeds that should be examined. These are the growing pains of the transition away from agronomically based range revegetation with exotic species to more ecologically based revegetation with native species.

Use of native seeds in revegetation often follows the current emphasis on multiple use of rangelands, as well as a desire to enhance ecosystem diversity and functionality and to conserve biological resources. Policies and practices of Federal agencies that manage large areas of public rangelands are in a state of transition toward increased emphasis of native species (Richards and others, this proceedings). Support or opposition to revegetation practices by various individuals and groups, including the use of native species, sometimes makes sense ecologically, economically, and practically, and sometimes does not.

Soil Stabilization, Weed Control, and Diversity

Because of their establishment, dependability, and vigor, exotic grasses are often used in rangeland revegetation when the priorities are soil stability or competitive weed control. But the same aggressive characteristics that make these exotics successful also result in their dominance, competitive exclusion of other species, and a lack of diversity. Comparisons of rangelands revegetated with exotic species with native rangelands in good condition are unfair because exotic seedings are usually done on degraded lands dominated by weeds and lacking diversity and positive watershed conditions (Ruyle and Roundy 1990). Although some seeded exotic species such as Lehmann lovegrass (*Eragrostis lehmanniana*) have spread (Anable and others 1992), most have not invaded native plant communities in good condition. The argument could be made that many areas seeded to exotic species are more diverse and functional than the degraded and weedy conditions that preceded revegetation.

Still, mixed seedings of exotics and natives often result in exotic monocultures that support little diversity and are susceptible to insect damage and other problems (Pyke 1996). One example is the dominance of intermediate wheatgrass (*Agropyron intermedium*) and smooth brome seeded on mountain slopes and aspen (*Populus tremuloides*) parks for forage and erosion control. In some areas these species dominate and exclude the native species, while on other sites they have been replaced by weeds such as tarweed (*Madia glomerata*) (Monsen 1997). Exotic grasses seeded in mixtures with native seeds after chaining pinyon (*Pinus monophylla*) and juniper (*Juniperus osteosperma*) communities to improve watershed conditions and wildlife habitat have often crowded out the native grasses over time (Walker and others 1995). The exotics may also reduce establishment of native forbs and shrubs included in the mix and limit natural reproduction of established shrubs on the site (Monsen 1997). The same thing also happens in mineland reclamation seedings, especially when fertilization favors growth of the exotic grasses (Redente and DePuit 1988).

An example of this dilemma for natural resource managers is illustrated by the Maple Mountain fire rehabilitation project on the Wasatch Front Range above Mapleton, UT. When the west slope burned in 1989 and again in 1994, citizens pressed for immediate rehabilitation efforts to prevent debris flows and property damage below these steep slopes. The burned area report recommended aerial seeding predominately of proven, dependable exotic grasses to quickly stabilize the slopes (USDA Forest Service 1995). The Utah Division of Wildlife Resources contributed seed of native sagebrush (*Artemisia tridentata* ssp. *vaseyana*) and white-stemmed rabbitbrush (*Chrysothamnus nauseosus* ssp. *albicaulis*) from their warehouse to diversify the mix and enhance wildlife values. However, stabilization of the slopes was dependent on the exotic, rather than native, species. Many mineland reclamation sites and other steep slopes have been stabilized by exotic species but now lack the value of native diversity (Schuman and others 1982).

It may not be possible to solve this dilemma by seeding exclusively native species in the first place, but perhaps exotic species seeded to stabilize the soil or recapture the site from weeds could subsequently be replaced by native species using interseeding (Stevens 1994) or patch seeding strategies. Whether seeding mixtures of exotic and native species will eventually become dominated by exotics or not depends on seeding rates, the particular species and site, and initial seedling establishment. Hard fescue (*Festuca ovina* var. *duriuscula*) was so aggressive in species trials in northeastern Washington, that after 30 years it had displaced many of the other species seeded in adjacent plots (Harris and Dobrowolski 1986). Although seeding mixtures of grasses, shrubs, and forbs can produce a mixed plant community, the established plant composition does not necessarily mirror the seed mixture. Doerr and others (1983) found that increasing the seeding rate of shrubs relative to grasses did not similarly increase shrub versus grass biomass of the established community. Irrigation and nitrogen additions initially favored grass more than shrub biomass. On fire rehabilitation projects in Idaho, the Bureau of Land Management has learned to encourage sagebrush establishment in conjunction with exotic grasses by drilling the grasses in the fall at less than 1 lb pure live seed per acre, followed by aerial broadcasting sagebrush seed later in the winter at 0.1 to 0.25 lb pure live seed per acre (Johansen 1997). They also alternate-row seed fourwing saltbush (*Atriplex canescens*) with exotic grasses to minimize competition between grasses and slower growing shrub species.

Failure of some native species to establish in the past may be due to inappropriate seedbed preparation or sowing technique (Young 1992). For example, small-seeded species such as sagebrush and rabbitbrush (*Chrysothamnus* spp.) may have been sown too deep when drilled like exotic grasses. Broadcasting these species into seedbeds roughened by chaining or other mechanical treatments has increased their establishment (McArthur and others 1995). Successful establishment of native species will increase as we learn to adapt our seeding strategies to their establishment requirements. New fluffy-seed drills and planters now make it possible to sow native seeds with appendages.

Seeding and maintaining diverse, native plant communities will require that we have a better understanding of competitive interactions and resource acquisition in time and space relative to the life cycles and life history strategies

of the species of interest, given relevant disturbance regimes. Although there are strong competitive interactions among many rangeland species, there are also many positive interactions that support increased diversity and production of appropriate mixtures (Call and Roundy 1991; Pendery and Provenza 1987; Rumbaugh and others 1982; West 1989). These interactions should be better understood and exploited to increase native diversity through revegetation.

Research aimed at improving establishment of native species in the face of exotic weed competition includes studies of the effects of nutrient availability on plant dominance (McLendon and Redente 1994), the use of promising new herbicides for weed control (Pellant 1995), the manipulation of germination rates by seed priming (Hardegree 1996), various studies on weeds and desirable plants at the population, community, and landscape scale (Pyke 1995), and modeling of seed germination and seedling establishment as a function of temperature and moisture in the seedbed (Christensen and others 1996). Unfortunately, the resources committed to determining solutions to increased weed invasion and fire frequency on Western rangelands are small compared to expenditures for fire control and rehabilitation.

Adaptation, Genetics, and Scale

One difficult but important question is just how native does our selection of plant materials have to be in revegetation to maintain adaptation and diversity (Jones, this proceedings; Rice and Knapp, this proceedings). Many exotic and native plant materials have been chosen in the past because they had broad adaptation and were useful for large-scale revegetation projects (Pyke 1996). Much past and current revegetation research involves testing plant performance of specific collections of populations of particular species to testing many different species and genera. Numerous field trials over the years have been helpful in producing recommendations of plant materials for specific climates and sites.

Past and continuing research has shown the ecotypic nature and wide genetic diversity of many wildland plants (McArthur and Tausch 1995). Some concerns about plant materials selection are that high genetic diversity may be necessary to maintain adaptation in dynamic environments, that nonlocal seed sources will not necessarily have adapted genomes, or that nonlocal sources may result in genetic pollution and loss of local genomes (Linhart 1995; Rhymer and Simberloff 1996). These concerns have led to changes in plant source identification, selection, and improvement approaches for wildlands (Meyer and Kitchen 1995; Pyke 1996; Young and others 1995). Of course, we lack an understanding of the genetics and reproductive biology and ecology of many wildland species, and that knowledge is necessary to speak intelligently in particular situations.

The agronomic approach to plant improvement has been to select or breed for plants with specific desirable characteristics. In so doing, genetic diversity is often reduced. The Natural Resources Conservation Service, Plant Materials Centers and other plant materials researchers in the past have taken this agronomic approach of collecting from many populations, evaluating the segregated collections in common environments, and increasing and releasing the best performers for similar environments (Englert and White 1997; Shiflet and McLauchlan 1986). Developing improved plants based on ecological principles involves discovery and characterization of plant materials from native populations, followed by possible selection or genetic manipulation for specific management needs (McArthur 1988). Some Plant Materials Centers are now developing nonsegregating methods such as convergent-divergent schemes to increase, rather than narrow, the genetic diversity of plant materials (Munda and Smith 1995). Researchers continue to try to determine the ecophysiological and morphological basis of adaptation to more easily evaluate plant materials as an alternative to lengthy field trials (Criddle and others 1994; Johnson and Asay 1993; Monaco and others 1996; Smith and others 1996).

An appreciation for the ecotypic nature of wildland plants has led to the concept and certification of source-identified plant materials (Currans and others, this proceedings; Vankus 1996; Young 1995; Young and others 1995). The Forest Service has implemented the approach of seed collection zones for commercial tree species but not for grasses, shrubs, and noncommercial trees. However, the Pacific Northwest Region of the Forest Service is developing techniques for increasing use of native species as evidenced by a native seed collection guide for the Wallowa-Whitman National Forest (Huber and Brooks 1993), a native plant project summary for the Mt. Hood National Forest (Cray and others 1995), and a native plant notebook for the Mt. Baker-Snoqualmie National Forest (Potash and others 1994).

Geneticist Howard Stutz has long believed that the dynamic and harsh environments of wildlands and especially mine spoils require high genetic diversity to allow persistence (Stutz 1983; Stutz and Estrada 1995). His observations of mortality of homozygous populations of fourwing saltbush (*Atriplex canescens* 'Wytana') support this belief. He suggests that for mine land reclamation, essential genetic diversity can be introduced by selection of superior forms from derived products of interspecific hybridization or by physically pooling seeds from collections of diverse ecotypes of *Atriplex* that have the same chromosome number. His best evidence of the first approach is the success of hexaploid *Atriplex obovata* crossed with hexaploid *Atriplex canescens*. The resultant hybrids are fertile, long-lived, and produce vigorous, fertile, segregating progeny with high phenotypic diversity. The success of this hybridization is evidenced by natural establishment of progeny in a harsh environment on the mine spoils of northern New Mexico (Stutz and Estrada 1995).

The smaller the spatial scale is for a particular revegetation project, the more practical will be the use of specific gene pools, as long as a seed source is available. The most practical approach should be to fit the demands for specific genetics to the scale and nature of the disturbance and revegetation problem. This approach should encompass everything from exotic generalists to native site specialists. Redente and others (1994) have proposed such a framework for plant materials selection for the National Park Service. They rank potential plant materials based on their ability to fulfill policy, protect resources, preserve genetics of local populations, and cover the spatial scale of disturbance within a particular management zone (table 2). This provides for a balance between absolute demand for local materials and

Table 2—Native plant materials used in revegetation in the National Parks will be ranked according to how well they fulfill revegetation objectives for different management zones (after Redente and others 1994).

Plant materials	Objectives	Management zones
Natural recovery	Policy	Natural
Collected on site	Resource protection	Cultural
Increased off site	Genetic preservation	Development
Commercial	Size characteristics	Special use

the reality of treatment for specific kinds and sizes of disturbance. Nonlocal soil stabilizers could appropriately rank ahead of local materials on critical sites susceptible to further degradation. Commercial sources of native seeds could rank high enough for use on larger disturbances where genetic integrity of a local population is not at risk. However, determining risk of loss of genetic integrity for species that cross pollinate depends on understanding the gene flow and dynamics of the population. Because this is usually not known, situations with true risks may be hard to identify.

Seed Availability and Practicality

The more specific and unique the genetic restrictions required for revegetation species, the less practical and more expensive it will be to supply them commercially (Bermant and Spackeen, this proceedings; McArthur 1988). Seed companies must make their money either by bulk sales or high specialty prices. Seed companies can often meet most needs, given enough advanced notice. Their success is based on warehousing a large amount of seeds of species with a reliable demand. In that regard, seed warehouses are important in creating a reliable market for native seed producers and for providing an available supply for unplanned situations, such as fire rehabilitation. The Bureau of Land Management's Regional Seed Warehouse in Boise, ID, stores about 450,000 lb of more than 40 species (Johansen 1997). About 20 percent of the plant materials represented are natives. The Utah Division of Wildlife Resources seed warehouse in Ephraim has been critical in providing native seeds for their own revegetation projects and for those conducted by the Forest Service and Bureau of Land Management. The current warehouses are inadequate to meet the demands for fire rehabilitation.

Research on effects of seed storage methods on seed viability and germination and special storage requirements for some species will be important as seed stocks are increased to meet future, more genetically specific demands. Methods of increasing native seed production will be needed to reduce prices for large-scale projects. We need improved equipment for sowing, harvesting, and cleaning native seeds. Procedures for ensuring native seed quality and integrity are being developed (Currans and others, this proceedings; Meyer and Monsen 1993; Stevens and others 1996; Vankus 1996).

There are great opportunities in the future for increasing the use of native plants to add value to rangelands. To fully realize these opportunities we will need to understand much better the biology of the plants and the ecology of their environments, while in the meantime being realistic and practical.

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Native Seed Policy and Practice

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Presentation Summary

Native seed policy for revegetation of range and forest lands is based on changing social values as well as advances in ecological knowledge. Natural resource managers have shifted from valuing introduced species for their general genetic and ecological robustness to reestablishing native species to maintain or restore the genetic and ecological integrity of native ecosystems. Addressing the scale-associated problems of reestablishing native plants on a site-specific basis has been increasingly recognized as an integral part of ecosystem management of large landscapes.

We reviewed the formation and implementation of native seed policy for fire rehabilitation and mining reclamation by the major public land management agencies in the United States: the Department of the Interior's Bureau of Land Management (BLM) and the Department of Agriculture's Forest Service. This review was based on interviews with agency personnel and analyses of existing statutes, formal policies, rules, and regulations. We found that while general policy direction for both the Forest Service and the BLM clearly emphasizes the use of native plants in fire rehabilitation and mining reclamation projects, specific policy objectives and project scale differ by agency and revegetation purpose. In contrast to mining reclamation efforts, fire rehabilitation projects generally aim to provide short-term watershed protection rather than long-term ecosystem biodiversity. Although fire rehabilitation projects typically involve thousands of burned acres, mining reclamation efforts usually affect hundreds of mined acres.

To determine the degree to which different policy objectives and project scales affect patterns of reclamation in actual native plant policy implementation, we examined the types and numbers of species included in seed mixtures used or recommended by the BLM in the State of Nevada on mine reclamation versus fire rehabilitation projects. Seed mixture data were collected from four BLM districts for 26 mine reclamation projects and 50 fire rehabilitation treatments. In general, the majority of species (10 out of 12) seeded on mined sites were natives. In contrast, slightly less than half (1.7 out of 4) of the few species seeded on fire sites were natives. The short-term policy objective of minimizing soil erosion, even at the expense of maintaining wildlife habitat, was reflected in the seed mixture data for the fire rehabilitation projects that we examined. These projects had significantly lower numbers and fewer species of native plants than mine reclamation sites in the same districts.

These findings suggest that overriding short-term policy objectives, supplemental funding restrictions, and free-market supply and demand economic cycles may be critical factors inhibiting native plant policy implementation on Western rangelands. Agency changes are needed to establish more consistency between native plant policy and practice. Policy directives need to be developed that are consistent within both the BLM and Forest Service and that are similar and clearly stated for all administrative levels. In addition, increased emphasis needs to be placed on developing the ecological and technical knowledge necessary for increasing native seed availability at reasonable local levels.

Related Publications

Richards, R. T.; Chambers, J.; Ross, C. 1998. Native seed policy and practice—a viewpoint. Journal of Range Management. 51(4). [In press].

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Rare and Endangered Species: Offsite Conservation at the Berry Botanic Garden and the Center for Plant Conservation Network

Edward O. Guerrant, Jr.

Abstract—Seed banking and other offsite (*ex situ*) conservation methods are increasingly being used to help conserve rare plant species in the wild. Offsite conservation collections provide a hedge against catastrophic loss of irreplaceable genetic lineages, and effectively complement onsite conservation efforts.

The Center for Plant Conservation (CPC) is a national network of botanic gardens and arboreta that seeks to store offsite genetically representative samples of our nation's most vulnerable plant species, and work with land managers to help conserve endangered species. The CPC's participating institutions can provide a knowledgeable partner to assist land managers in solving a wide range of problems in rare plant conservation.

Populations of a great many native species are rapidly disappearing as a consequence of habitat destruction and competition with exotic species. The long-term implications of habitat fragmentation are troubling even for common, competitively dominant species (Kareiva and Wennergren 1995; Tillman and others 1994). Population loss is an especially acute problem for rare and endangered species, which are frequently known only from a small number of populations.

The Berry Botanic Garden (Portland, OR) is the Pacific Northwest member of the Center for Plant Conservation (CPC) which is a national network of 28 gardens and arboreta (table 1). Our common goal is to collect genetically representative samples of our nation's most vulnerable plant species while it is still possible to do so, and to maintain them in long-term *ex situ* (offsite) storage.

Stored seed are a means to an end—the conservation of species in the wild. Our work is intended to supplement and complement, not replace, *in situ* (onsite) conservation efforts. By storing seed, we reduce the chances that the genetic legacy of particular populations or species will be completely lost if they should become extirpated. Offsite samples also create options otherwise unavailable to land managers. Stored seed can be used to reintroduce extirpated populations, and to augment existing ones.

We in the CPC are attempting to provide unique regional conservation resources. In so doing, we actively seek to work with a wide variety of public and private land managers, and other interested parties such as native plant societies. By themselves, offsite measures are not enough to save endangered species. But, in partnership with land managers, offsite methods can significantly reduce the chances that our most vulnerable species will be lost in the foreseeable future.

Problems

Populations of many if not virtually all native plant species are rapidly being lost. The root causes are an ever increasing human population, and our use of natural resources. A primary direct effect on plant populations is the habitat destruction that often accompanies human land use. The resulting fragmentation of remaining habitat and isolation of remnant populations only exacerbates the problem by making the remaining populations more vulnerable to extirpation (Gilpin and Soulé 1986). An important indirect effect has been through increased competitive and other pressures

Table 1—The Center for Plant Conservation participating institutions. The national office is located at the Missouri Botanical Garden, St. Louis, MO (http://www.mobot.org/CPC).

The Arboretum at Flagstaff, Flagstaff, AZ
The Arnold Arboretum of Harvard University, Jamaica Plain, MA
The Berry Botanic Garden, Portland, OR
Bok Tower Gardens, Lake Wales, FL
Chicago Botanic Garden, Glencoe, IL
Denver Botanic Gardens, Denver, CO
Desert Botanical Garden, Phoenix, AZ
Fairchild Tropical Garden, Miami, FL
Garden in the Woods, Framingham, MA
Amy B.H. Greenwell Ethnobotanical Garden, Captain Cook, HI
The Holden Arboretum, Kirtland, OH
Honolulu Botanical Gardens, Honolulu, HI
Harold L. Lyon Arboretum, Honolulu, HI
The Morton Arboretum, Lisle, IL
Mercer Arboretum and Botanic Gardens, Humble, TX
Missouri Botanical Garden, St. Louis, MO
National Tropical Botanical Garden, Lawai, HI
The Nebraska Statewide Arboretum, Lincoln, NE
The New York Botanical Garden, Bronx, NY
The North Carolina Arboretum, Asheville, NC
North Carolina Botanical Garden, Chapel Hill, NC
Rancho Santa Ana Botanical Garden, Claremont, CA
Red Butte Gardens and Arboretum, Salt Lake City, UT
Regional Parks Botanic Garden—Tilden, Oakland, CA
San Antonio Botanical Garden, San Antonio, TX
Santa Barbara Botanic Garden, Santa Barbara, CA
University of California Botanical Garden, Berkeley, CA
Waimea Arboretum and Botanical Garden, Haleiwa, HI

In: Shaw, Nancy L.; Roundy, Bruce A., comps. 1997. Proceedings: Using seeds of native species on rangelands; 1997 February 16-21; Rapid City, SD. Gen. Tech. Rep. INT-GTR-372. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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experienced by native plants from nonnative species (see Parker and Reichard 1997), which humans have transported around the globe, both intentionally and unintentionally.

In addition to the obvious negative impacts of habitat fragmentation on biodiversity, recent theoretical work suggests we may be running up an extinction debt, which will come due over the next 50 to 400 years (Kareiva and Wennergren 1995; Tillman and others 1994). Surprisingly, the model suggests that species most at risk in a permanently fragmented landscape are currently the more common, competitively superior species. Even though we depend heavily on some of these species for their ecological and economic values, very little concern has been expressed to protect competitively dominant species from the corrosive effects of habitat fragmentation.

Of most immediate concern are species we know to be currently most vulnerable—rare and endangered species. We are able to rationally rank the relative risk of species and populations, and thus plan accordingly, because the Heritage Programs maintain extensive, population-specific data bases on rare plants in each State. Unfortunately, the Endangered Species Act, which has been at the center of much rare plant restoration efforts, has been used in a manner not unlike a hospital emergency room: Care is provided only when the problems are most acute.

Schemske and others (1994) reviewed all 91 U.S. Fish and Wildlife Service recovery plans for plants that were available in 1992. They found that the modal number of populations per species was just one, and over half had five or fewer populations extant. That many species survive in just one to five populations is similar to other surveys of plants in the United States and Australia (Brown and Briggs 1991; CPC 1991; Wilcove and others 1993).

Population number is just one measure of a species' vulnerability. Population size is another. Even in species that still have many surviving populations, population sizes can be quite small. For example, the endangered western lily (*Lilium occidentale*), with which we at the Berry Botanic Garden have been working for many years, is known historically from some 60 populations (Guerrant and Pavlik 1997; U.S. Fish and Wildlife Service 1997). Somewhere between a third and half of the known western lily populations have been extirpated. Given that the species was described only a century ago (Purdy 1897), this works out to the loss of one population every 3 to 5 years. The median size of the surviving populations is between 26 and 35 individuals. Fewer than 10 populations appear to have 100 or more individuals, of which maybe four have as many as 1,000 (Guerrant and Pavlik 1997; U.S. Fish and Wildlife Service 1997). Unfortunately, this is not an extreme, isolated case. Wilcove and others (1993) found that the median population size for plants at the time of listing by the U.S. Fish and Wildlife Service was fewer than 120 individuals, and the modal interval was between 11 and 100 individuals. Recent work on the genetics of small populations (Lande 1995; Lynch and others 1995) suggest the genetic effective population size (N_e) necessary for long-term survival is an order of magnitude higher than previously thought (on the order of 5,000 or greater, rather than 500).

Clearly, many species are on the brink of extinction. Those of us who work with rare and endangered plants have been forced, as a practical necessity, to develop procedures to conserve and restore species where every population and every individual count.

Solutions

The task of conserving our nation's most rare and endangered plant species is enormous. It cannot be accomplished by any one entity, public or private, or by any single method. Perhaps the best hope for significant progress lies in the aggressive and coordinated use of all available means at our disposal. Public education about the reality, severity, and broader long-term implications for human welfare of population and species loss may ultimately be as important than more direct conservation measures (see Ehrlich and Ehrlich 1996).

There is a broad consensus among conservationists that the best and first line of defense involves protecting and managing rare plant populations and their habitat for the benefit of those species. Nevertheless, even though there is no substitute for onsite efforts, they are not always adequate. Falk (1987, 1990, 1992) has developed the concept of Integrated Conservation Strategies, which incorporates the coordinated use of onsite and offsite components in concert with appropriate legislation, supporting scientific research, and public involvement. Even the most enlightened land management practices, diligently applied and supported with sufficient resources, will not always be successful in maintaining rare plant populations. This is not to criticize or denigrate land managers, it is simply a recognition of the stochastic, even chaotic behavior of species comprised of few, small populations often occupying degraded habitats. Collection and offsite storage of seeds is increasingly being accepted as an integral part of comprehensive planning for rare plant conservation.

The Berry Botanic Garden Seed Bank for Rare and Endangered Plants of the Pacific Northwest was established in 1983. We currently have in long-term storage over 3,000 accessions of over 250 of our region's most vulnerable plant species (Guerrant 1997). In 1985, the Berry Botanic Garden became a charter member of the Center for Plant Conservation.

The Center for Plant Conservation comprises 28 participating institutions throughout the United States (except Alaska), with a national office at the Missouri Botanical Garden in St. Louis, MO (table 1). Our common goal is to bring into long-term storage genetically representative samples of our nation's most vulnerable plant species, to maintain these samples, and to develop the knowledge of how to use them to establish self-sustaining populations in the wild, should that become necessary.

Offsite Conservation Measures—a Means to an End

Offsite conservation measures are but one tool among many. They are neither an alternative to onsite conservation efforts, nor an end in themselves. Offsite measures are intended to complement onsite efforts. The primary conservation value of offsite samples will ultimately be measured by their effect on the long-term survival prospects of endangered species in the wild.

For offsite collections to become a meaningful conservation resource, we must do the following: (1) collect genetically representative samples; (2) keep them alive for long periods of time, and be able to germinate and grow them to maturity; and (3) know how to use stored seed to establish self-sustaining populations in the wild. To address the first and last of these tasks, the CPC has sponsored two symposia, which formed the basis of volumes that culminate in genetic sampling (Falk and Holsinger 1991) and reintroduction guidelines (Falk and others 1996). The intermediate task, of keeping stored samples alive for long periods of time, is the subject of a manual available from the CPC (Wieland 1995).

Genetic Sampling Guidelines

Sampling of nonseed propagules, such as taking and rooting of cuttings, is in principle the same as for seeds. However, in practice, maintenance of nonseed propagules is a vastly more difficult and resource intensive proposition. For the sake of brevity, I will refer only to seeds.

Molecular or ecological genetic studies are available for only a tiny fraction of plants, most of which are of more common species. Therefore, the CPC (1991) has sought to provide guidelines to assist member gardens and others in developing sampling designs for particular species. The guidelines seek to make the most of whatever knowledge is available for a rare species. They are intended to help conservationists develop rational, scientifically based sampling programs for particular situations in the absence of resource-intensive, species- and population-specific, molecular or ecological genetic data.

The guidelines take the form of a hierarchically arranged series of questions to consider (table 2). From most inclusive to least, they are:

1. Which species should be sampled? (most endangered)
2. How many populations should be sampled? (1-5)
3. How many individuals per population should be sampled? (10-50)
4. How many seeds per individual should be collected? (1-20)
5. When should collection be spread over 2 or more years?

The guidelines (table 2) offer a recommended range of sample sizes, key biological factors to consider, and factors affecting sampling decisions toward the higher or lower ends of the recommended ranges. These guidelines can also be used to inform sampling decisions of more common species. However, it should be noted that the guidelines were designed for use on rare species with very limited numbers of populations. They are intended as a practical response to the perceived need that for many of these species time is in short supply. Clearly, sampling only five populations will not adequately sample many widespread species. For example, at least four and possibly five genetically based ecotypes have been identified for ponderosa pine (*Pinus ponderosa*), which ranges widely throughout western North America (Millar and Libby 1991).

The guidelines have found a wider audience than the CPC participating institutions, for which they were primarily intended. They have been used as a basis for guidelines prepared by the Botanic Gardens Conservation International (BGCI), a global organization with over 400 member institutions in 75 countries, and by the Australian Network for Plant Conservation (Falk, personal communication; Guerrant and Pavlik 1997). Nevertheless, they have critics (for example, Hamilton 1994). Guerrant and Pavlik (1997) have suggested that the recommended sample size ranges suggested (table 2) may need to be revised upward, perhaps significantly so. Nevertheless, because the recommendations are couched in relative terms, with factors to consider that would tend either to increase or decrease sample size in any particular case, their usefulness and value transcend the actual sample sizes suggested.

The guidelines are discussed in greater detail in Falk and Holsinger (1991) and Guerrant and Pavlik (1997).

Seed Storage

Collecting genetically representative samples sufficiently large to support baseline studies of germination and propagation requirements, periodic viability tests, and one or more reintroduction attempts is just the first step. The seeds must also be stored alive for many years, if not decades to centuries, if their potential conservation value is to be realized.

Seed storage technology has been the subject of much work for a long time, but it is not yet a settled, mature discipline. Seeds of most species fall into one of two relatively discrete categories, orthodox and recalcitrant. Orthodox seeds can survive desiccation to very low moisture contents, and can generally be stored safely at subfreezing temperatures. Alternatively, recalcitrant seeds cannot survive desiccation to the point where freezing seeds is an option. We in the temperate zones are fortunate, because a large majority of species in our regions of the world have orthodox seeds. The primary exceptions are large, wet seeded species such as oaks (*Quercus*), and many nut trees (such as *Corylus* and *Juglans*), and some wetland species, such as wild rice (*Zizania*). However, many wetland species have orthodox seeds. For example, Guerrant and Raven (1995) found at least 64 of 69 (93 percent) species native to the Willamette Valley wet prairie habitat to have orthodox seeds. Many species in lowland wet tropical areas have recalcitrant seeds, which present a much greater conservation problem.

The basic procedures used to store seed at The Berry Botanic Garden (Guerrant 1997; Guerrant and McMahan 1995) were patterned after international standards offered by the International Board for Plant Genetic Resources (Ellis and others 1985). Once a species or population is chosen, the process begins with seed collection. Ideally, the seed is rapidly transported to the seed bank, where drying is begun immediately, after which the seeds are cleaned, counted, and drying finished. The seeds are then packaged in airtight containers, in which they are stored frozen. The development of germination and propagation protocols follow.

The long accepted international standards, drying seeds to equilibrium at 15 percent relative humidity (RH) and 15 °C and storing them in airtight containers at −18 °C, have recently been challenged by workers at the USDA National Seed Storage Laboratory in Fort Collins, CO (see Vertucci and Roos 1990, 1993; Vertucci and others 1994). Nevertheless, there is still a consensus that seeds of orthodox species are best dried and stored frozen. The controversy has to do with exactly how dry and how cold seeds should be stored for

Table 2—Center for Plant Conservation: summary of sampling guidelines for conservation collections of endangered plants.

	Decisions			
	Which species to collect?	**How many populations sampled per species?**	**How many individuals sampled per population?**	**How many propagules taken per individual?**
Recommended range	—	1-5	10-50	1-20
Target level of biological organization	Species	Ecotype and population	Individual	Allele
Key considerations	Probability of loss of unique genepool Potential for restoration or recovery	Degree of genetic difference among populations Population history	Log of population size Genetic mobility within population	Survivability of propagules Long-term use of collection
		Factors affecting sampling decisions		
	High degree of endangerment	**High diversity/limited gene flow among populations**	**High diversity among individuals within each population**	**Low survivability of propagules**
Collect more	*Experiencing rapid decline*	*Imminent destruction of populations*	*Observed microsite variation*	*Planned use for reintroduction or restoration program*
	Few protected sites	*High observed ecotypic or site variation*	*Mixed-mating or outcrossing*	
	Biological management required	*Isolated populations*	*Fragmented historical populations*	
		Potential for biological management and recovery	*Small breeding neighborhood size*	
	Recently or anthropogenically reduced	*Recent or anthropogenic rarity*	*Low survivability of propagules*	
	Feasibility of successful maintenance in cultivation or storage	*Self-fertilization*	*Extremely large populations*	
	Possibility of reintroduction or restoration			
	Economic potential	*Herbaceous annual or short-lived perennial*	Boreal distribution	
		Early- to midsuccessional stage	Gymnosperm or monocot	
		Gravity-, explosively-, or animal-dispersed seed	Woody perennial	
		Dicot or monocot	Late-successional stage	
		Temperate-tropical distribution	Animal- or wind-dispersed seed	
		Wind-dispersed seed	Temperate-tropical distribution	
		Outcrossing wind-pollinated	Early- to midsuccessional stage	
		Late-successional stage	Dicot	
		Observed similarity among populations	Herbaceous annual or short-lived perennial	
		Long-lived woody perennial	Self-fertilizing	
	High integrity of communities	*Gymnosperm*	*Explosively or gravity-dispersed seed*	
	Many protected sites	*Boreal-temperate distribution*	*High survivability of propagules*	
	Natural rarity	*Protected populations or naturally rare*	*Large breeding neighborhood size*	*Low annual reproductive output (indicates multiyear collecting strategy)*
Collect less/fewer	*Stable condition*	*Closely clustered populations*		
	Low degree of endangerment	**Low diversity/extensive gene flow among populations**	**Low diversity among individuals within each population**	**High survivability of propagules**

Note: Four basic practical decisions are addressed: which species to conserve, and the number of populations, individuals, propagules to be sampled for each species. For each decision, a recommended range is shown, along with an indication of the relevant level of biological organization and a summary of key considerations. Factors that influence the sampling decision are listed in detail, with the most significant factors shown in italics. Factors suggesting larger or more extensive collections are shown at the top of each column, while those suggesting smaller or less extensive collections are given at the bottom.

optimal long-term seed survival (Ellis and others 1991; Smith 1992; Vertucci and Roos 1990, 1991, 1993). In short, Vertucci and her colleagues maintain that the standard recommendations dry the seeds too much, at the expense of long-term seedling vigor and seed survivorship. Furthermore, they suggest that the optimal moisture content of seeds for maximal seed survivorship (and thus the temperature and relative humidity to which they are equilibrated) varies as a function of storage temperature (Vertucci and Roos 1993; Vertucci and others 1994).

In lieu of a consensus recommendation from those most knowledgeable in seed storage protocol, the CPC has sought to locate a middle ground acceptable to both camps, pending scientific resolution of the question (Wieland 1995). We at the Berry Botanic Garden dry seeds to equilibrium at 20 percent relative humidity and 15 °C. We both dry and store seed in the concrete encased seed vault. When they are ready, seeds are sealed in metal-foil bags and stored in a modified home-type freezer at –18 °C. The freezer is kept in the seed vault because it is the safest location at the Garden. Several other CPC gardens operate their own seed banks, and all participating institutions have access to the superb storage facilities at the USDA Seed Storage Laboratory in Fort Collins, CO.

Reintroduction

The most direct way in which stored seed can contribute to population survival is for use as stock for reintroduction, after extirpation of the wild population from which it was collected. Stored seed may also be used to augment, or increase the size of extant populations. Stored seed contributes indirectly to long-term population survival by allowing managers the luxury of implementing experimental land management practices, because they have a backup in case of disaster.

This potential benefit of storing seed for conservation purposes is perhaps best exemplified by the case of Malheur wirelettuce (*Stephanomeria malheurensis*) (Guerrant 1996b; Guerrant and Pavlik 1997; Parenti and Guerrant 1990). The species was known only from a single wild population that became extinct in 1985-1986. Dr. L. Gottlieb (UC Davis) was able to provide seed to the Berry Botanic Garden, which he had been storing since he collected it in the 1960's and 1970's. The Garden germinated the seed and provided growing plants to the Bureau of Land Management and U.S. Fish and Wildlife Service for an experimental reintroduction back into the site it had occupied before it apparently became extinct.

Reintroduction is a much more complicated affair than simply broadcasting seed or planting plants. In addition to the biological challenges, which are great, there are many legal, policy, philosophical, and even political considerations that bear on the decision to reintroduce a species to the wild. In 1993, the CPC organized a conference to clarify these and many other issues. The proceedings of this conference form the core of *Restoring Diversity: Strategies for the Reintroduction of Endangered Plants* (Falk and others 1996), the final section of which contains guidelines for developing a rare plant reintroduction plan.

The guidelines are presented as a series of 11 questions to consider (table 3). The first four address the question, "Is reintroduction appropriate?" And the last seven, "How will reintroduction be conducted?" In addition to considerations of any legal, regulatory, or policy context that might apply, and basic criteria that can be used to determine whether a species is an appropriate candidate, a key consideration is whether a reintroduction is being considered as mitigation or as part of recovery. The interests of conservation are not well served by trading away existing habitat that supports a rare plant, for the uncertain fate of a newly introduced population. Reintroduction may be a necessary even critical tool for recovery, but is not considered sufficiently reliable generally to constitute an appropriate mitigation tool.

Among the core findings of the symposium are the virtual consensus among practitioners that the science of reintroduction is in its infancy, and that reintroductions are most fruitfully conducted as well-designed scientific experiments, designed to test explicit management oriented hypotheses. See Pavlik and others (1993) for an excellent example of a well-designed and executed experimental reintroduction. Pavlik (1995) and Guerrant and Pavlik (1997) go on to show how knowledge gained in such experimental reintroductions can be used to manage wild populations.

Long-term monitoring of the results (Sutter 1996), and evaluating success (Pavlik 1996) must be integral parts of any reintroduction project. Pavlik (1996) distinguishes between project success and biological success. Even if an extensive project involving multiple plantings in different seasons and years, of many treatments, each with large sample sizes, may be considered a success even if all plants die without reproducing. If we were able to show that we do not have the knowledge to successfully reintroduce a species, we have learned something useful: Conserving and properly managing existing habitat is essential to the survival of that species.

Table 3—Reintroduction guidelines (Falk and others 1996).

Is reintroduction appropriate?

1. What guidance can be found in existing policies on rare species reintroduction?
2. What criteria can be used to determine whether a species should be reintroduced?
3. Is reintroduction occurring in a mitigation context involving the loss or alteration of a natural population or community?
4. What legal or regulatory considerations are connected with the reintroduction?

How will reintroduction be conducted?

5. What are the defined goals of this reintroduction, and how will the project be monitored and evaluated?
6. Has available ecological knowledge of the species and its community been reviewed? What additional knowledge is needed to conduct the project well?
7. Who owns the land where the reintroduction is to occur, and how will the land be managed in the long term?
8. Where should the reintroduction occur?
9. What is the genetic composition of the material to be reintroduced?
10. How will the founding population be structured to favor demographic persistence and stability?
11. Are essential ecological processes intact at the site? If not, how will they be established?

Regional Conservation Resources

The Berry Botanic Garden, like many other CPC participating institutions, actively seeks to provide regional conservation resources. Our seed banking work, and related research are our unique contribution to rare plant conservation. But we also work cooperatively with a variety of land managers on a variety of research, monitoring and survey projects.

For example, the Berry Botanic Garden has been involved in many cooperative projects with State (Oregon, Washington, California, and Idaho) and Federal agencies (especially, the Bureau of Land Management, Forest Service, and U.S. Fish and Wildlife Service), private land managers (such as The Nature Conservancy) and native plant societies (such as Native Plant Society of Oregon). The New England Wildflower Society, which operates the Garden-in-the-Woods, is a CPC participating institution. They organized the New England Plant Conservation Program (NEPCoP: Anon. 1992), which is a consortium of over 65 public agencies and private organizations which seeks to organize and implement plant conservation action for an entire region. They recently published a comprehensive, annotated list of New England plants in need of conservation (Brumback and Mehrhoff 1996).

Much of our work at the Berry Botanic Garden involves cooperative research projects with State or Federal agencies on rare plants. For example, we have surveyed for (Raven 1994, 1995a) and monitored (Raven 1996) rare plants. We have also conducted a 6 year stage-based transition matrix demographic study of the elegant trout-lily (*Erythronium elegans*) (see Guerrant 1996a), which was supported by genetic analyses (Guerrant and others 1996) and experiments designed to elucidate possible causes of an apparent population decline (see Raven 1995b). Elegant trout-lily is known only from five populations, the second largest of which was thought to be in decline. We have also been involved in reintroduction attempts of malheur wirelettuce (Guerrant 1996b; Guerrant and Pavlik 1997; Parenti and Guerrant 1990) and western lily (Guerrant 1995; and unpublished data), both of which are endangered.

Similar work goes on at many other CPC gardens. For example, Machinski and others (1997) of the Arboretum at Flagstaff, AZ, conducted a demographic study of *Astragalus cremnophylax* var. *crymnophylax* with the aim of evaluating the effects of human trampling (and fencing to restrict trampling) on the survival and growth prospects of that species. Dawson (personal communication), at the Denver Botanic Gardens (another CPC garden), is conducting long-term demographic and other ecological studies, and a reintroduction project with the U.S. Fish and Wildlife Service, of the Federally endangered *Astragalus osterhoutii*.

There are many other examples, but these few will serve to make the point. The CPC institutions have much to offer land managers in the way of assistance with plant conservation efforts. Our unique contribution is in offsite conservation, but the CPC participating institutions have much to offer professional expertise in a variety of areas.

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Ensuring Identity and Quality of Native Seeds

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Abstract—State seed certification programs offer Source Identification services that improve the likelihood of procuring site-adapted native seed. Native shrub species Source Identified in the Western United States increased from zero in 1993 to approximately 60,000 lb in 1994 and 150,000 lb in 1995. State seed testing laboratories provide broad seed expertise, but more research is needed to develop standard seed testing procedures for many economically important native species. The Natural Resource Conservation Service (NRCS) is actively providing documented native germplasm of many grasses, forbs, and shrubs.

Ensuring Seed Identity

Proper seed source identification and an accurate measurement of seed quality are essential to successful revegetation and restoration projects using native species. Seed certification agencies, seed testing laboratories, the Natural Resource Conservation Service, and proper seed storage have important roles in the process of ensuring seed identity and quality.

Knowing the identity of native seeds can make the difference between a successful planting and a failure. For instance, sagebrush (*Artemisia* spp.) is currently collected in large quantities from natural stands. There is a strong demand for Wyoming big sagebrush (*A. tridentata wyomingensis*), but seed yield from wild stands is often not adequate to meet the demand.

Basin big sagebrush (*A. tridentata tridentata*) is also traded in the Intermountain region and generally yields more seed than Wyoming big sagebrush. When sagebrush is traded without Source Identification, there is the possibility that Basin big sagebrush seed will be substituted for Wyoming big sagebrush seed, placing the range planting at risk. The planting technician may not even consider attributing seeding failure to poorly adapted or misidentified germplasm.

Users of native seed have a growing interest in knowing the origin of the germplasm they buy. A mechanism for third-party verification of germplasm origin is the Source Identification service available from member agencies of the Association of Official Seed Certifying agencies (AOSCA). Contact your local county extension agent or Natural Resource Conservation Service representative to learn where to find your State Certification agency.

Seed Certification

Certification agencies were created in the United States in 1919. More than 90 years ago university plant breeders, agronomists, and seed growers began to recognize the need to establish some control over the marketing of valuable germplasm. Abraham Fultz, for example, in 1862, released a new wheat variety called "Fultz wheat." Various seed companies began producing and marketing the new variety and, because there was no market control, it was soon marketed under 24 different trade names. "Silvermine oats" was released in 1895 and was subsequently grown under 18 different names (Hackleman and Scott 1990). Consequently, the need was recognized to control and provide for uniform naming of cultivars. Also, prior to 1919, each State independently developed its own nomenclature describing better classes of seed such as "inspected," "registered," or "certified." Such differing categories caused much confusion, so AOSCA created uniform categories. AOSCA also began to address the concern of college agronomists who were finding that within a few years of release, unique traits of varieties of corn, alfalfa, clover, and soybeans were being genetically diluted by inadequate seed handling methods. AOSCA developed a system for limiting seed generations and controlling handling procedures to ensure genetic purity of Certified varieties.

The concept of "Certified" seed arose from the early concerns about crop identity, naming, quality categories, and genetic purity. The certification system was developed so that any named variety that was genetically uniform and stable, as described by the breeder, could be entered in the local State certification program. The certification agency would then monitor the increase of the seed through successive generations. The plant breeder would supply Breeder seed, usually to a foundation seed project. The foundation seed project would then plant a small field with the Breeder seed and produce Foundation generation seed from that field. Foundation seed would be used to plant a Registered field, which produced Registered generation seed. Foundation or Registered class seed is usually sold to private growers who use it to plant the fields that produce Certified seed. Bannock thickspike wheatgrass (*Elymus lanceolatus lanceolatus*), Eski sainfoin (*Onobrychis viciifolia*), and Rangelander alfalfa (*Medicago sativa*) are three examples of named varieties produced as Certified seed.

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The official Certified blue tag is the final proof that the seed in the bag is actually Certified seed. One Certified tag must be on each bag to verify that the seed has passed all certification requirements in the field and that it meets minimum purity and germination standards.

Source Identification

Named varieties can be bought as Certified seed, but what about native species such as needle-and-thread (*Stipa comata*)? Needle-and-thread is a highly sought-after native species, selling at $40 to $50 per lb. To date, needle-and-thread is generally only available in small quantities from hand collections. How can the buyer be sure of the origin or of site adaptation?

Assurance comes through Source Identified seed. The AOSCA mechanism to provide third-party verification of wild land collected native seed identity is called the "Source Identified" class. This class was developed years ago to serve the interests of the tree seed industry. Recently, AOSCA adapted the Source Identified class for use with nonvarietal seed collections of shrubs, forbs, and grasses as well as trees. Source Identified seed will always carry an official yellow tag on each bag of seed (Young and others 1995).

Source Identified seed is provided by seed collectors who want to participate in a certification program. Seed collected from a wild stand or from a cultivated field of a native species such as basin wildrye (*Leymus cinereus*) can be entered in the State certification program to become Source Identified. The end user is then assured of the elevation and county of origin of that seed collection.

Although some variation exists between the States, the Source Identification procedure works as follows. To enter the program the seed collector submits an application to his State certification agency. The agency records and files the application. The collector notifies the agency when the collection will be made so that the agency can conduct random on-site inspections. Unfortunately, due to personnel restrictions, probably only 10 percent of the applications will actually be site inspected. The integrity of the program would increase with more inspections of a greater percentage of applications. After the seed is ready to market, the collector or the seed dealer requests Source Identified tags for the number of pounds collected. The agency then prints and mails the official yellow Source Identified tags to the collector.

The Source Identified services offered by State certification agencies for wildland shrub, forb, and grass seeds are relatively new. Even though tree seeds have been Source Identified for over 30 years, the class was only recently activated in 1993 for other kinds of seed. Utah has been the leading State in using the class of Source Identified seed. In 1994 Utah Source Identified about 60,000 lb of seed (Young 1996). In 1995 the Utah Crop Improvement Association reported Source Identifying a total of 143,000 lb of seed. Species Source Identified included Wyoming big sagebrush, silver sagebrush, Gardner saltbush, prostrate kochia, fourwing saltbush, Louisiana sage, and winterfat. In 1995, Wyoming Source Identified 2,880 lb, Nevada processed a handful of applications, Colorado Source Identified two cultivated fields, and Montana filed one Source Identified application. The six other Western States did not handle any Source Identified seed.

Users of native seed should know that certification programs and procedures have already been developed for varieties that can be purchased as blue tag Certified seed. Native seed users can also ask for Source Identified seed of a chosen elevation and county of origin to fit the area to be planted. The Source Identified tag on each bag of seed verifies the origin. The Source Identified programs are new and it may take the industry a few years to respond to new "Source Identified needs." Also, Source Identification requests must be made in advance of the collection season. Like many seed products, availability of Source Identified seed will respond to market demand.

Ensuring Seed Quality

Determining market value of native seeds depends on accurate evaluation of seed purity and viability. Seed law varies among States, but as a general rule, all seed must be tested by a licensed laboratory before or at the time of sale.

Standard Seed Testing

A purity test is used to determine the percent by weight of the seed lot that is composed of intact seeds (sometimes whole fruits). The sample is subdivided into pure seed (test species), other crop seed, weed seed, and inert material. Each category is weighed to determine percent composition.

Viability is expressed as the percentage of the total number of seeds capable of producing healthy seedlings. This percentage is determined in one of two ways. First, laboratory germination tests (using four replications of 100 seeds) are conducted under specified conditions resulting in the germination of all or part of the viable seed fraction. Germinants are classified as normal if they possess all essential structures needed to produce plants under favorable conditions (AOSA 1996). Abnormal seedlings are counted as dead. Ungerminated seeds are classified as dormant, hard (impermeable to water), or dead. Total percent viability is equal to the number of normal seedlings, plus the dormant seed, plus hard seed, divided by the total number of seed tested.

A second method for determining seed viability is the tetrazolium or TZ test. In this test, seeds are prepared in various ways for staining with a 0.1 or a 1.0 percent solution tetrazolium chloride. Embryos are examined after a specified time. Live embryonic tissue stains pink to red, while dead tissue does not stain (Grabe 1970). Dormant seed stains as well as nondormant seed. Pure live seed (PLS) percentage is calculated by multiplying the purity percentage by the viability percentage (as determined by a germination or a TZ test).

As an example, a seed lot with purity of 95 percent and a viability of 84 percent would have a PLS value of 80 percent. If this lot had a bulk weight of 100 lb, it would have a PLS equivalent weight of 80 lb. Seed is usually sold based on PLS pounds or bulk weight, with minimum tolerances specified for both purity and viability. Thus, if the seed in the above example were offered at $6.00/PLS lb or $4.80/bulk lb, the total value would be the same at $480.00.

For many species, mean seed size and weight can vary considerably among seed lots. As a result, the number of seeds per PLS pound may also vary significantly. The range in number of seeds per pound for three native species as estimated using five to 22 collections each is shown in table 1. These examples show that number of seeds per pound can vary as much as 400 percent for some species. This information could be valuable in calculating seeding rates. Unfortunately, however, seed dealers and users generally do not request a seed weight test.

Research Needed to Develop Tests

In theory, the Association of Official Seed Analysts (AOSA) standards ensure accuracy and consistency in seed testing. For many species, actual practice approaches this ideal, but for numerous species this is not the case. Here we consider major causes of inaccurate or inconsistent seed test results and make recommendations to improve the testing of native seeds.

For many species, and in some cases whole genera, no uniform standards exist for testing seeds. Consequently, each laboratory is free to use whatever procedure is deemed adequate for the species. Procedures adopted from related species are often successfully substituted. TZ tests are common for species without rules and are often adequate indicators of viability even though they reveal nothing concerning seed dormancy. To illustrate the problem, we reviewed the native species offered by two Utah-based seed companies. A total of 253 native species were represented in the catalogs. Table 2 shows the number of native species offered for sale that have or do not have standardized AOSA rules. A total of 170 species, or 67 percent, do not currently have rules, and new species are being marketed each year.

One might argue that many of these species are not commonly on the market. This is true. However, when they are available they are generally expensive, accentuating the need for accurately determining seed quality. In addition, large quantities of seed of species with no testing standards are sold annually. Table 3 lists examples of native species with no existing AOSA rules. Many of these are economically important revegetation species.

A second problem concerns species that have rules that have proven to be inadequate. Tests for these species produce inaccurate or inconsistent results either because variation in seed lot attributes is greater than the variation encountered when the rule was originally developed, or because of variation among laboratories and analysts in application of the standards. Firecracker penstemon (*Penstemon eatonii*) illustrates the problem. The AOSA germination rule for firecracker penstemon calls for 8 weeks of prechill followed by 21 days warm incubation (AOSA 1996). Unfortunately, the seeds of most collections of this species do not respond to prechill treatments of less than 12 weeks (table 4). Inexperienced analysts might easily misinterpret TZ results for this species because healthy penstemon embryos often stain a light pink, a condition indicative of questionable seed health for many other species (Grabe 1970). Seed analysts working with seeds of this or similar

Table 1—Variability in number of seeds per pound for three native species (Kitchen 1995, unpublished data).

Species	Seeds per pound	Collections
Curlleaf mountain mahogany	43,000 - 61,500	5
Lewis flax	155,000 - 233,000	13
Needle-and-thread	34,500 - 132,500	22

Table 2—Native Western species with AOSA approved rules for seed testing, based on seed offered in catalogs of two Utah seed companies.

Type	With rules	Without rules
Grasses	23	34
Forbs	38	76
Trees/shrubs	22	60
Total	83	170

Table 3—Examples of native Western species without AOSA rules for testing.

Common name	Scientific name	Named cultivars
Grasses		
Idaho fescue	*Festuca idahoensis*	Yes
Spike muhly	*Mulenbergia wrightii*	Yes
Alkaligrass	*Puccinellia* spp.	Yes
Alkali sacaton	*Sporobolus airoides*	Yes
Needle-and-thread	*Stipa comata*	No
Sedges	*Carex* spp.	No
Forbs		
Arrowleaf balsamroot	*Balsamorhiza sagittata*	No
Globemallows	*Sphaeralcea* spp.	Yes
Asters	*Aster* spp.[a]	No
Buckwheat	*Eriogonum* spp.	Yes
Indian paintbrush	*Castilleja* spp.	No
Beeplant	*Cleome* spp.	No
Shrubs		
Saltbushes	*Atriplex* spp.[a]	Yes
Ceanothus	*Ceanothus* spp.	No
Sumac	*Rhus* spp.	Yes
Currant	*Ribes* spp.	No
Buffaloberry	*Shepherdia* spp.	Yes
Snowberry	*Symphoricarpos*	No

[a]One species with rules.

Table 4—Firecracker pentsemon seed germination in response to prechill (Meyer 1992).

Seed source	Chill duration (weeks) 0	4	8	12	16
	Germination percentage				
Snow's Canyon	91	71	100	100	100
Enterprise	3	6	6	70	93
Long Canyon	12	27	62	98	100
Thistle	10	9	12	67	90
Glendale	2	5	12	47	45
Payson Canyon	2	10	6	43	98
Bluebell Flat	1	0	1	15	64

species should be aware of this and learn to accurately interpret TZ staining patterns. A new set of germination standards with a longer prechill or other more effective treatment should be adopted for this species.

The issue of TZ test interpretation is much larger than that of a single species. For many who buy and sell native seeds, TZ is the test of choice, and germination tests are the exception because TZ testing takes only a few days compared to germination tests taking a couple to many weeks. Seed technicians of all skill levels need more frequent opportunities to calibrate TZ interpretive judgment with germination tests.

Sagebrush seed lots pose a particular challenge to the seed analyst. Seeds are minute at 2 to 2.5 million per lb. Acceptable purities for marketable seed lots range from 10 to 20 percent with stem, leaf, fruit, and flower fragments composing the bulk of the material. Variation within and among bags of seed of the same lot is problematic. Many lots have numerous immature or shriveled seeds that, when counted in the germination test, reduce the viability percentage substantially. However, if they are placed with inert matter, they have practically no impact on the final purity analysis, while viability percentages rise significantly. Finally, sagebrush seeds are sensitive to storage humidity and temperature and are relatively short-lived (Welch 1996; Welch and others 1996). Thus, viability percentages can change over rather short periods. Reports of highly variable test results for this species are common.

We recommend that all those who deal with the seeds of native plant species support research to develop testing standards for species that do not have them and to improve upon AOSA standards that have not performed adequately. We encourage more frequent use of paired germination and TZ tests to improve the interpretive skills of seed analysts, and thus the accuracy of tests. Buyers and sellers of native seeds should periodically request laboratories to perform both viability tests. The cost for an extra test is minimal when compared to the differences in estimated values of incorrectly tested seed lots.

Germplasm Development With Native Species

The Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture has a long history of working with introduced and some native species to develop useful conservation plants. The Plant Materials Program mission is to test and evaluate plants from many origins for solving conservation and soil erosion problems in the United States.

The focus of the 26 NRCS Plant Materials Centers (PMC's) has now changed to concentrate on North American native plants for conservation, restoration, revegetation, and rehabilitation. Currently, 90 to 98 percent of all NRCS plant material studies involve native plants. This work involves interagency cooperation with the goal of developing methods and techniques for plant propagation, establishment and maintenance of native plantings, and continued on-site monitoring of PMC studies to provide technical information to the public.

To date, the NRCS has released approximately 100 cultivars of North American plant species such as Hederma pine lupine (*Lupinus albicaulus*), Bison big bluestem (*Andropogon gerardii*), and Salado alkali sacaton (*Sporobolus airoides*). Native plant releases are usually done in cooperation with other Federal and State agencies. In most cases, the NRCS PMC's have not purposely manipulated the genetics of plants when selecting and increasing cultivars. Many of the native plant varieties were selected not only for rehabilitation or revegetation, but also as sources for forage for wildlife and domestic livestock. Breeder or original seed of released cultivars are maintained by the NRCS Plant Materials Centers according to high standards of genetic and mechanical purity consistent with most seed certification programs. Two of the biggest advantages of using NRCS native plant materials is that the origin is known and they are more readily available. Lists of available native seed and plant materials can be obtained from NRCS offices (Englert and White 1997).

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Genes on the Range: Ecological Genetics of Restoration on Rangelands

Kevin J. Rice
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Presentation Summary

To effectively restore populations of native species in Western rangelands, resource managers will need to understand the ecological and evolutionary processes that shape the genetic structure of both herbaceous and woody range plants. Although there is currently an emphasis on understanding patterns of adaptation in response to natural selection, other evolutionary forces such as gene flow and genetic drift can have a strong influence on the genetic architecture of rangeland species. Using examples from our current research on perennial bunchgrasses and oaks, we discussed the relative merits of different types of traits and markers in describing genetic structure and adaptive patterns in range plants. In general, molecular markers such as isozymes or RAPDs (randomly amplified polymorphic DNA) are useful for describing gene flow and detecting the effects of genetic bottlenecks. However, because these molecular markers are often neutral to the effects of natural selection, they are not good indicators of local adaptation. In contrast, quantitative (polygenic) traits such as plant flowering time or acorn size are (1) more likely to be under the influence of natural selection and (2) more likely to affect overall plant fitness. Thus, these types of quantitative traits are more useful in detecting local adaptation.

The effect of plant breeding system on local adaptation results from the major impact of breeding system on gene flow rates. Gene flow is a evolutionary force that is often as strong as selection. As a result, if a plant is highly outcrossing, then gene flow can be strong enough to override the influence of natural selection. Strong gene flow can thus reduce the capacity of natural selection to create locally adapted populations even across strong environmental gradients.

The capacity of a single genotype to express different phenotypes in different environments is known as phenotypic plasticity. Phenotypic plasticity can be adaptive, especially in environments where the local conditions change at a rate more rapid than the generation time of the organism. Our research on blue oaks has demonstrated that water-use efficiency of seedlings exhibits phenotypic plasticity that is potentially adaptive in terms of seedling growth rates. In addition, analyses of differences among seedlings produced from different trees (maternal families) indicate that plasticity in water-use efficiency may itself be under genetic control. This capacity of single genotypes to acclimate to rapidly changing environments may contribute substantially to the preservation of genetic variation within populations. This within-population genetic variation is extremely important because it represents the evolutionary potential of the population for further response to selective challenges in the future.

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Genetic Considerations for Native Plant Materials

T. A. Jones

Abstract—Genetics need to be considered when making intelligent choices regarding native plant materials. Critical components include informed decisionmaking, a coherent collection strategy, and a willingness to consider a variety of plant material types. Genetic issues should be considered within the larger context of land management. Some species exhibit considerable ecotypic variation and merit close matching of the ecogeographic area of site and material. Such species may genetically fix site-specific variation, which may be reflected in released material. Close matching of site and material is less critical for species with greater genetic uniformity. Some species have well-documented technical problems that require vigorous collection and evaluation efforts, innovative multiple-component approaches, or genetic manipulation to make them economically competitive in the seed industry. The goal of interdisciplinary scientific teams should be to increase land managers' flexibility to implement seedings in the best interest of the land and those who use it.

The genetic composition of plant material used in projects for land restoration, reclamation, and rehabilitation is a high-profile topic of interest to a wide variety of scientists, managers, policy makers, and nongovernmental organizations (Johnson and Mayeux 1992; Knapp and Rice 1994; Linhart 1995; Meyer and Monsen 1993; Millar and Libby 1989; Walker 1992; West 1993). A thorough understanding of genetic issues related to native plant materials is useful because of the controversial nature of this aspect of natural resource management. Seeding scenarios range from no intervention to permanent seedings. Informed decisionmaking, a coherent collection strategy, and willingness to consider a variety of plant material types are three elements of a successful genetic approach.

Decisionmaking

Decisionmaking regarding plant materials is no different than for any other aspect of natural resource management. Risks may emanate from either inaction or action. While risks are always present, they need not be an impediment if skillfully identified and balanced to maximize the probability of success.

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Risks of Inaction

Risks of inaction include the failure to seed properly or in a timely manner. Undesirable consequences of inaction include soil erosion, watershed and water quality deterioration, and invasive weed encroachment. If action is delayed because the most preferred plant material is not available, the seeding effort may become tragically self-defeating. By necessity, land managers need to adopt the best affordable technology available to protect the soil resource and to defend against weed invasion. Many land management problems have been exacerbated because action was not taken at the appropriate time.

Risks of Action

Risks of action, or the making of mistakes in choosing plant materials for seedings, have been generally described as "genetic pollution" (Rice 1992). While many seedings involve land where many species have been extirpated, genetic pollution concerns only those lands where remnants of the original native populations are still present. The concern is that a nonlocal source of a native species may "swamp" the remnant population via gene flow. Gene flow is the transfer of genetic material from one population to another, in this case through pollination of plants of the remnant population by the nonlocal source. The resulting seed is not representative of the remnant in a pure sense. Gene flow is greater for wind-pollinated than for animal-pollinated species, and has minor importance for self-pollinated species (Govindaraju 1988).

Some see gene flow as a significant problem and suggest that seed used on the site be restricted to that originating from the remnant (Linhart 1995). In cases where no local seed source is available, Millar and Libby (1989) proposed seeding with introduced species instead. They argue that these could be selectively eradicated at a later date, whereas local genotypes could probably not be reclaimed following intermating with nonlocal natives.

The negative impact of swamping, however, may be countered by positive attributes of gene flow. Gene flow has been described as a "handmaiden" as well as an "adversary" to natural selection (Spieth 1979). Under certain conditions, gene flow may disrupt evolution by cancelling the influence of selection for local adaptation (Linhart 1995). Specifically, evolution is constrained when gene flow between the nonlocal and remnant populations is at equilibrium. Under other conditions, gene flow may generate desirable new genetic combinations to be spread throughout the species' range (Slatkin 1987, 1994). Selection for local adaptation may continue as long as interpopulation gene flow is not at equilibrium. Selection is more effective at establishing local

differences than the random process of genetic drift, which allows loss of genes in small, isolated populations susceptible to inbreeding (Slatkin 1987).

Besides intermating, local genotypes may be displaced by competition from nonlocal natives. As opposed to swamping, undesirable competition may occur not only with cross-pollinating, but also with self-pollinating, apomictic, and vegetatively propagating species. Greater initial aggression by nonlocal natives may or may not relate to long-term site adaptation. While many doubt that a native plant could possibly be regarded as a "weed," in such an instance these plants fit the elementary definition as "plants out of place."

Seeding Scenarios

Seeding decisions for disturbed lands are made in the context of four possible scenarios varying in degree of human intervention. Often, no seeding is required after disturbance because plant survival is high and seed banks are intact. Natural succession can effectively operate to maintain a functional ecosystem.

Sometimes, however, the components necessary for natural succession are present, but a temporary nonpersistent seeding is needed to protect the soil and to provide time for natural succession to generate suitable ground cover. Regreen™, a sterile wheat (*Triticum aestivum* L.) x slender wheatgrass (*Elymus trachycaulus* [Link] Gould ex Shinners) hybrid, establishes quickly, controls erosion, and then quickly disappears as natural succession proceeds. Slender wheatgrass, blue wildrye (*E. glaucus* Buckley), Canada wildrye (*E. canadensis* L.), and mountain brome (*Bromus marginatus* Nees) are native, short-lived perennial grasses that have also filled this role in some areas.

Assisted succession may be required when ecosystem structure and function have been seriously impaired. In this scenario, multiple steps of human intervention are required (Sheley and others 1996). Assisted succession is appropriate in the expansive areas of the Intermountain West now dominated by annual weedy grasses (Hironaka 1994). Squirreltail (*E. elymoides* [Raf.] Swezey) is an early-seral, short-lived, perennial grass capable of coexisting with these annuals (Hironaka and Sindelar 1973; Hironaka and Tisdale 1963). This ability may improve success of follow-up seedings of later seral, longer lived species such as bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve) and, still later, big sagebrush (*Artemisia tridentata* Nutt.).

Finally, permanent seedings including long-lived perennials, such as big sagebrush, basin wildrye (*Leymus cinereus* [Scribn. & Merr.] A. Löve), bluebunch wheatgrass, antelope bitterbrush (*Purshia tridentata* [Pursh] DC.) are important when appropriate to provide for a specific use. In the past, permanent seedings have been thought of as tools for consumptive uses such as livestock grazing, but currently, nonconsumptive uses such as recreation and wildlife habitat are seen as equally important.

Coming to a Decision

Our objective, then, is to balance the risks of action and inaction in the context of the appropriate seeding scenario. Making an informed choice of plant material should be part of decisionmaking. Ecology, physiology, and genetics specialists may function as "corners" of a triangular interactive team to develop plant materials to effect problem solving. However, a team of an ecophysiologist, physiological geneticist, and conservation geneticist would be able to impact problems at an even deeper level because the team members themselves are interdisciplinary in orientation. While interaction has not been a feature of natural resource management in the past, ecosystem management directives provide an incentive for bringing together disparate disciplines to work toward solutions for natural resource problems.

But scientists don't make land management decisions. Land managers do. Land managers operate with a more complex set of constraints than scientists because they also must deal with sociological and economic factors. Some thought should be given as to whether seeding decisions are driven by science or philosophical values. I submit that these decisions are, in fact, based on values held by individuals or society, but I am hopeful that they will be made in the framework of scientific knowledge. The scientific team can support land managers by providing a variety of technically feasible options. Because both values and science may contribute in different ways to the decision, it is important to have a defensible rationale for the chosen path. Then, even if a project fails in certain respects, careful study of the results may provide valuable instruction for the future.

Collection Strategy

Collection strategy can benefit by considering genetics. Geographic analysis is a new approach that utilizes existing technology familiar to land managers (personal communication, S. L. Greene, USDA-Agricultural Research Service, Prosser, WA). Geographic analysis can identify high-priority collection areas, assist managers in choice of the most preferred plant material from that available, and define the "niche breadth" of a species. Geographic analysis uses Geographic Information System (GIS) data layers to identify and group contiguous or noncontiguous areas and their boundaries, gradients, and degree of homogeneity (patchiness). Some GIS data layers include MSS (multispectral scanner) and TM (thematic mapper) Landsat Satellite Imagery (topographic and vegetation patterns), a digital elevation model (elevation and terrain), and digitized soil and climate (abiotic environment) and road (points of access) maps. Ecogeographic areas and their interfaces identified on maps provide promising locations for collection. On-the-ground position is matched with mapping point using a Geographical Positioning System. Geographic analysis is expected to be effective when the biology of the targeted species promotes genetic differentiation among populations (such as self-pollination, low pollen production, and poor dispersal, or poorly developed seed dispersal mechanisms), the environment is heterogeneous enough to exert selection pressure, and the landscape restricts gene flow (personal communication, S. L. Greene).

At the time of collection, data on specific habitat characters may be recorded from the site. Suggested data for permanent data base records include soil texture and pH, seasonality of precipitation, anthropogenic disturbance (such as logging, grazing, settlement), elevation, slope,

aspect, landform (such as ridgetop, basin, ravine, roadway, or talus), dominant tree, shrub, and herbaceous species, degree of canopy light penetration, and landscape patchiness (Steiner and Greene 1996).

Patterns of genetic variation among species vary greatly, even among predominantly self-pollinated species. Green needlegrass (*Nassella viridula* [Trin.] Barkw.) is remarkably genetically uniform despite its distribution throughout the Great Plains from Alberta to New Mexico (personal communication, J. G. Scheetz, USDA-Natural Resources Conservation Service, Bridger, MT). However, its relative, Indian ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkw.) displays considerable intra and interpopulation variation (Jones 1990; Jones and Nielson 1996). Genetic differences can be readily documented and correlated with locality in either clinal or heterogeneous (patchy) patterns (Linhart 1995). But these may result from nonselective forces such as gene flow, genetic drift, or historical events as well as from selective forces (Hedrick 1986). Long-term studies of plant adaptation across a wide range of environments suggest that it cannot be presumed that materials are unadapted because of nonlocal origin. Under some circumstances, even genetically polluted material may provide valuable new raw material upon which natural selection can operate.

Plant Material Type

A third genetic consideration is plant material type. Options include site-specific materials, multiple-component materials, and bred (genetically manipulated) materials.

Site-Specific Material

Certification procedures for site-specific material have been approved by the Association of Official Seed Certifying Agencies (1997). Release of site-specific material as precultivar germplasm is appropriate when any of the following conditions hold: specific ecotypes are needed for restoration, commercial seed sources are inadequate, a high potential for immediate use is present, or commercial potential is limited (Young 1995). Site-specific materials may be recognized for release as one of four classes: source-identified (identified as to collection location), selected (shows promise of superiority in comparison with other populations when grown at a common location), tested (exhibits stable heritability in progeny-testing), and cultivar (demonstrates adaptation over a broad range of environments and has a promising market demand). Each class may be wildland collected or field grown. Material may proceed from the first of these classes to the fourth along a "track" as a population is compared to others and progeny tested. Tracks may be manipulated or natural, that is, with or without intentional genetic modification. Within each class, a seed lot may be identified by numbers of generations removed from the original on-site collection. For example, wildland-collected seed is G_0, the first increase from G_0 is G_1, the increase from G_1 is G_2, and so forth. Most commercially available native plant materials have been released by the Plant Materials Centers of the USDA-Natural Resources Conservation Service. They would have qualified as natural track cultivars under this system.

Multiple-Component Materials

Multiple-component materials combine a species' genetic diversity within an individual site or ecogeographically similar sites. This approach provides an opportunity to balance risks. Bulk mixtures of self-pollinating accessions (Marshall and Brown 1973; Munda and Smith 1995) amalgamate material from a variety of sites collected from a common ecogeographic area. At least part of the material would be expected to be adapted to the seeding site. An analogous approach for cross-pollinated species, proposed by Millar and Libby (1989), may be referred to as the multiple-origin polycross. In this case, intermating creates new genotypes from constituent populations.

Self-pollinated species may naturally balance biological risk by maintenance of ecologically relevant biotypes in the population (Jones and Nielson 1996). An Indian ricegrass population collected near Star Lake, McKinley County, NM (T-593) exhibits three biotypes distinguishable on the basis of plant and seed morphology. Seed mass (mg) and lemma (outer hull) thickness (um) are 8.6 and 180 for jumbo, 4.9 and 95 for globose, and 2.7 and 54 for elongate seed polymorphisms. Jumbo seed are highly dormant (0 percent germination following prechill), globose seed are intermediate (29 percent), and elongate seed are highly germinable (75 percent). Their coexistence implies that the Star Lake environment is favorable to the germination characteristics and persistence of each biotype.

The ecological cultivar, or "ecovar" (Wark and others 1995), represents another multiple-component approach to balance risk. The ecovar concept emphasizes maximizing genetic diversity while making practical allowance for genetic manipulation for seed production traits including yield, retention, and germinability. Ecovars are being developed for western Canada, in particular, and are intended to serve a specific region, such as southeastern Alberta.

Bred Material

The third plant material type—that in which plant breeding has played an important part—has aroused controversy in the native plant user community. In my opinion, each of three conditions must hold to justify the intensive effort of plant breeding. First, the species must be relatively important but limited by a specific problem, a so-called "genetic lesion." Second, less manipulative means, such as those discussed above, must be incapable of addressing the problem. Third, the tools of plant breeding must be able to solve the problem by selection for traits elucidated by ecological, physiological, or genetic concepts. Plant breeding has limitations and cannot solve all plant materials problems. On the other hand, those who disparage plant breeding on philosophical grounds may wish to learn more about its potential and limitations from practitioners working with native plants.

The convergent-divergent selection approach combines the multiple-component and breeding approaches. It may be used to develop widely adapted cross-pollinated materials by practicing artificial recurrent selection on a multiple-origin polycross. Convergent-divergent selection was originally proposed by Lundquist and others (1979) and modified

for native plant materials by Munda and Smith (1995). Following intermating (polycross) of materials of multiple origin corresponding to a defined ecogeographic area (convergent phase), the intermated population is established at various target sites corresponding to the ecogeographic area. The intention is to provide an opportunity for selection at many locations in the targeted ecogeographic area (divergent phase). Material from all locations is then returned to a common site for intermating for a second convergent phase. This process is repeated to achieve the objective of wide adaptation within the defined ecogeographic area.

Conclusions

Decisionmaking, collection strategy, and plant material type all have genetic components to be considered when seeding native species. Together, they provide a framework for planning by the land manager. Land managers must balance risks and maximize potential for a favorable return on investments of time, personnel, and fiscal resources devoted to seeding operations. Scientists committed to providing options increase land managers' flexibility in dealing with external factors such as limited budgets, personnel shortages, bureaucratic directives, and management of interest groups with various perspectives. This flexibility should improve land management success despite changes in the land and the clientele that uses it.

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Native Species in the Commercial Seed Industry

Don Bermant
Scott Spackeen

Abstract—The selection of species to use in reclamation projects is not only a matter of what is ideally desired of the plant community composition, but also what is available and affordable. Pricing depends on variables such as commercial popularity of certain species or varieties, the difficulty involved in production or harvesting, and demand versus production in any given year. The small and specialized reclamation seed industry makes every effort to respond to changing trends in the popularity of native plants, improved varieties, or hardy introduced species. Over years of rising and falling demand, the seed industry has made over a thousand reclamation varieties commercially available. Nevertheless, if a project requires large quantities of rare species or locally specific accessions, it will be necessary to plan with a seed supplier well in advance to meet that need.

We at Granite Seed Company continually face questions about providing native seed material to the reclamation industry. Almost every week we find ourselves in another conversation about the controversies surrounding native seeds. We hope this symposium will contribute to solving some of the problems with planning for planting native species in land reclamation. While other speakers here may hash out the definition of just what constitutes a native plant and about native seed policy, we are here to speak about the practical aspects of providing seed to meet the growing demand for native species. The intent to plant natives, no matter how ideologically or scientifically valid, will be meaningless without the availability of the material to put into the ground.

We will outline the processes and issues involved in getting seed to market. And if there is one thing we hope you come away with, it is that you need to keep your seed company informed of your needs well in advance. If we know what you want, we will be sure to do everything we can get it for you. Think of the land reclamation industry and the reclamation seed industry as partners in reclaiming or improving the land.

It is our business to provide you with the products that you request. If you wanted to plant moon rocks we'd try our darndest to get them for you. However, you have to realize that once we get them for you, you may not like the price. The selection of species to use in reclamation is not only a matter of what is ideally desired of the plant composition, but also what is available and affordable.

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History of the Seed Industry

Providing seed for use in reclamation is not new to the seed industry. However, the land reclamation industry, and the facet of the seed industry that specializes in reclamation seed, are relatively new. The first major event that essentially launched the reclamation industry was the soil bank days of the 1950's when this Nation was suffering from severe wind erosion. This erosion was the result of vast acreage of land being void of a significant vegetative cover. To arrest this problem the U.S. Department of Agriculture implemented a plan to revegetate this land. Approximately 28 million acres were revegetated, requiring some 200 million lb of seed. Thus, an industry was created.

During this period, the USDA called upon the Soil Conservation Service (SCS), now known as the Natural Resource and Conservation Service (NRCS), to solve a problem. The concern was that many accessions of seed were being planted that did not establish too well. So the SCS developed Plant Material Centers across the country that were charged with the task of studying and creating varieties of species that would have a known geographic distribution of adaptation. The government wanted to develop varieties that were known to perform well and that could be raised successfully for seed production. The Plant Material Centers have done an excellent job. They have provided us with numerous varieties of native plants. In fact, most of the materials they have released are simply native selections without any genetic alterations. They have released few varieties that were the result of crossing accessions.

In the 1950's several researchers with the Great Basin Experiment Station in Ephraim, UT, began experimenting with native materials for use in the restoration of big game range habitat. Most materials they worked with were shrubs. They experimented with ways to collect, clean, plant, and cultivate this seed. In many ways, these pioneers helped pave the way for the native collection industry that we know today. Much of the work they did came in handy when the U.S. Government passed the Surface Mining Control and Reclamation Act in 1977.

This act, also known by the acronym SMCRA, required any company engaging in surface mining on public land to restore that land to its premining plant and animal composition and productivity. At that time there was no source available for many of the plants that grew on these lands, so the seed industry was called upon to provide this material.

The industry turned to the research done by the Soil Conservation Service, from whose work the seed industry was able to produce and supply many of the grasses that were requested. The industry also turned to the work done by the Great Basin Experiment Station to learn ways to provide shrub and other wildland collected material.

The need for native seed material again increased in 1987 when President Reagan used a Federal Highway Act to mandate that 0.25 percent of all landscape funds for reclamation of Federal highways had to be spent on wildflowers. This act encouraged the seed industry to produce a diverse selection of wildflower seed for use on our Nation's highways.

In the 1980's along came the Conservation Reserve Program. The CRP was designed to revegetate highly erodible crop lands with perennial plant cover, much like the program of the soil bank days. The CRP resulted in the revegetation of more than 32 million acres of farm land. At an average of 8 pure-live-seed lb planted per acre, the program required 256 million pure-live-seed lb of seed. A large portion of the seed planted through the CRP is native.

Throughout most of this time, land management agencies such as the Bureau of Land Management, Forest Service, Bureau of Indian Affairs, National Park Service, State agencies, and others were purchasing seed materials for the improvement of their lands. Until relatively recently, most of the material requested was for improved nonnative introduced grasses that exhibited good drought tolerance while providing maximum forage. There is now a trend away from the use of introduced species and toward natives.

In our opinion, the recent interest in the use of natives came to a head in 1994 when President Clinton issued an edict from the White House to all Federal land management agencies that said, "When practical, the use of local native plants should be used for land reclamation." This edict has prompted the land management agencies such as the Forest Service, BLM, and BIA to request, not just natives, but natives that have been harvested within a certain proximity of the site being revegetated. Although this edict is not law, it has often been interpreted as law.

Current Challenges

This has created interesting challenges for the seed industry. The main problem is that we simply do not have local collections of large quantities of seed from every niche and corner of the United States. We wish we did, but we don't because we simply do not know which part of the country is going to require this seed year after year. Take 1996, for example. More than 6 million acres burned in the Western United States. We had no idea where those fires were going to occur. Consequently, when local natives were requested for revegetating these burned lands, the material was not available. The seed industry was able to supply native material, but just not locally collected— same species but different accessions.

Throughout all of the years of rising and falling demand, the seed industry has been able to bring to market the seed the public has requested. That's our business. Over the years, we have made over a thousand varieties commercially available to the reclamation industry.

Land reclamation is a specialized industry. Compared to other industries, there are not a whole lot of us doing this for a living. Consequently, the seed used in reclamation projects is also specialized. In fact, many of the seed companies servicing the reclamation industry can be found at this conference. Compared to most of the seed that is traded in this country, seed used in reclamation is difficult to find. It is not like we can go to the Chicago Board of Trade and purchase a trainload of bitterbrush seed. Instead, the seed industry is able to meet demand only when seed merchants can successfully predict what the demand will be. And we have to do that years in advance of the year in which we bring seed to market.

So how do we know what to collect or field produce? And how do we know how many pounds to keep on hand? We know from history. We stock the species and quantities that our customers traditionally ask for and use. When we analyze our inventory and decide what we are going to grow in the coming year, for sale the following year, our decision is based on past usage of the species.

Occasionally, the seed industry finds that it does not have enough species, varieties, accessions, or pounds requested by the reclamation industry. There are typically three reasons for the shortage: (1) crop failure; (2) unusual increase in demand, such as was created in 1996 from the 6 million acres that burned; and (3) the request for material that the reclamation industry has not typically needed or wanted in the past.

The seed industry needs as much help from you as possible to ensure that we have the seed you need. If you have a large project, or require seed that is not typically available, you can help guarantee that you will get what you want if you inform your seed company at least one season in advance. This way the seed company can make plans to either farm or collect the seed for you.

Seed Pricing

The price of seed can vary widely. Typically, seed that is harvested by hand from the wild is the most expensive seed, ranging upward of several hundred dollars per pound for some flowers. Field-produced seed is less expensive and can be as low as less than a dollar per pound for certain grasses or legumes. To give you a better idea of why prices vary so much, I will discuss three groups: grasses, flowers, and shrubs.

Grasses

The group easiest to acquire and accumulate for sale are grasses. Consequently, these are also the least expensive group of the three, even though a few specific species such as needle and thread (*Stipa comata*), can be quite costly. Compared to forbs and shrubs, most grasses are easy to cultivate and easy to harvest by machine. In addition, there has been a lot of research on grass species and varieties used in reclamation. As mentioned, the NRCS has developed improved varieties ever since the soil bank years, and most of their research has been directed at grasses. This has been great research because, not only have they developed native

cultivars, but also identified their range of adaptation. So, for example, we know that Arriba western wheatgrass is typically adapted to the southern portion of its range, while Rosanna western wheatgrass is a more northerly cultivar. The NRCS work has been valuable to the reclamation industry, providing the basis for a lot of the specifications that we are requested to bid.

Flowers

The next easiest group to acquire are the forbs, or wildflowers. Many of these may also be cultivated and mechanically harvested. However, even when farm grown they are more expensive than grasses because of the difficulty of controlling weeds while growing them. Because wildflowers are broadleaf plants, it is not possible to use broadleaf herbicides to control weeds. Instead, it is necessary to hand cultivate the weeds. The NRCS has also developed a few wildflower species for us to market. For example, they developed Appar Blue Flax and Bandera Rocky Mountain Penstemon. Again, these varieties have specifically identified ranges of geographic adaptation and have consequently become important in land reclamation.

Shrubs

The third group, shrubs, are all collected in the wild. For all practical purposes, no shrubs are cultivated for commercial production. People are trying but, as yet, with little success.

For example, the industry uses more than 100,000 lb of fourwing saltbush (*Atriplex canescens*) per year, which would appear to be enough to make it a profitable crop. Three varieties of fourwing saltbush are available for cultivation: Wytana, Santa Rita, and Rincon. Regardless of which of the three is planted, it takes approximately 3 years to establish a stand from which seed can be harvested, and during that establishment period there is no return on investment in land and maintenance. Furthermore, seed production on these varieties is extremely variable. When the stand is mature enough to produce seed, there is no guarantee it will have a crop year after year. Finally, there is no mechanical means to harvest the seed. Field-cultivated fourwing saltbush has to be hand-harvested just like the seed that comes from the wild.

Collecting Seed

It is not easy to hand-collect seed. In fact, I think it is one of the most difficult jobs. People who collect seed are linked closely to the land. What I mean is that to be a good seed collector requires you to be familiar with plant communities and their environments across vast areas. You must be cognizant of weather patterns and events. You must be familiar with the phenology of the species you are collecting. And you must be a hard worker.

Seed companies in the reclamation business must develop and maintain strong relationships with their collectors to make sure that the materials we want are the materials that get harvested. At Granite Seed Company, we insist on knowing the exact location of all wild-collected seed.

The first problem in collecting seed is to find a stand large enough to be worth harvesting. An ideal stand is one in which all of your time can be spent collecting seed and very little time walking between plants looking for one ripe to harvest. It is difficult to find a stand that fits this criterion. While it is relatively easy to find large stands, or monocultures, few will produce enough seed to warrant a harvest. And it is extremely rare to find a stand that produces large quantities of seed two growing seasons in a row, probably because of the energy required by the plants to produce this seed. Each stand, and many plants, have a little seed on them year after year, but rarely will a plant population or monoculture have large quantities of seed on every plant. When it does, this is a seed collector's mother lode!

Once the collection site is found, the seed collectors must obtain permission from the landowner—creating an anxious moment. After miles and miles of driving in a pickup, after days of looking, the collector finds a beautiful stand of seed, and also finds that some people just plain don't want you tromping around on their land. Fortunately, most land management agencies have put systems in place to allow for harvesting seed off public land, and with luck the stand is immature enough to wait while the necessary permission is obtained.

Collection areas are most easily found when the plants are in flower because they are then easiest to spot from great distances. It takes a lot of skill to know when you need to come back for the actual harvest. A good seed collector can estimate just when the time is right, say, 3 or 5 weeks hence. In doing this, the collector must watch the weather. A wet pattern can delay the harvest while a turn toward hot and dry can speed up the harvest time.

Assuming the collectors accurately determined when to harvest, they must then get crews out there. And, as with any job, there are employee problems. Seed picking is not glamorous work. You are out there bent over all day, working in the hot sun and wind, in a cloud of pollen and dust, collecting seed often so small it requires finding 2 million of them to make up just 1 lb. And employees can get frustrated. Because seed is purchased by the pound, the vendor sometimes finds rocks and dirt and other things that add weight to the bags, rolling across their seed cleaning equipment when the seed is being processed for sale. Fortunately, most collectors are great to work with.

Once the seed has been collected, it is imperative to dry it immediately. Fresh seed has too much moisture to be placed into a bag. If packed into a bag before it is allowed to dry it will heat up and kill the seed. Therefore, the seed must be laid out on tarps in the wild to dry. This might sound easy, but you are fighting with the elements. A slight wind can put your tarp into the next county, and a rain storm can ruin your collection entirely.

From here, the seed is brought back to the processing facility where it is cleaned to remove sticks, stems, and other foreign material that would make it difficult to plant. Once processed, a sample of the seed is sent to a certified seed testing lab to be tested for purity and germination. When we get the seed test back, with luck we find that the seed has germination and that there are no noxious weeds present that would keep us from offering the seed to the market place.

So you can see, this is not an easy chore. It is not easy to find seed every year. Frequently, whole ecotypes in specific geographic areas do not produce commercially harvestable seed in a given year.

Planning Ahead

To some reclamation managers, it is not good enough to use native seed material that is adapted to an area; instead, they want to use native seed material that has come from within a specific distance from that area. Sometimes this is just plain impossible to do because plants just might not be producing a seed crop that year. And if they are producing a crop that year, the crop may be small, thereby causing the price to be high. You then have to ask yourself whether or not it is worth purchasing the expensive seed, or if it is more practical to plant another accession of the same species that is also adapted to the site.

If it is imperative to plant local natives, you can increase your chances for success by planning with your seed supplier several years in advance. Using this strategy will give us more time to collect from a specific area. You may want to contract your seed supplier to custom harvest seed from your own site and have us produce it and supply it back to you.

It is relatively easy to find many accessions of locally collected shrub material in stock because all of the shrub material comes from wildland stands, and these stands are located throughout the country. Unfortunately, when it comes to grasses and forbs, seed companies are reluctant to spend too much time and money on stocking local accessions. It is simply much more economical to produce field-cultivated seed that has a known geographic adaptation. I do not know of any research that proves you would get superior success from using locally collected grass or forb accessions than it is to plant the adapted varieties currently available in the market place. That is why seed companies do not invest a lot of time and money to inventory these more expensive site-specific natives, when reclamation managers might decide that they don't need them after all.

While it is important to match the ecotype that is being planted with the ecotype from which the seed comes, no one has proven, for example, that Wyoming big sagebrush collected from a stand in eastern Utah is going to harm the environment in northern Nevada. We do know, however, that the seed will grow there and will produce a good stand of sagebrush plants. Some ecological systems are vast regions, such as the Northern Great Plains or the Great Basin, and plant material originating from isolated sections of these regions may be compatible with the plants in other sections of these regions.

So I think this is a great time for government and academia to research this matter. I am not saying that Granite Seed Company is for or against the use of local accessions. On the contrary, we will attempt to provide you with whatever you ask for. However, we and the entire seed industry are going to be careful about what we stock. If we spend much money on stocking accessions that are more costly than the same species harvested from more conventional means, then we can get caught holding the ball if the reclamation industry decides that it is not important enough to spend the extra money to purchase locally collected materials. We want to do the right thing for the reclamation industry, but without research we do not know whether or not the acquisition of local natives is the right thing to do.

Case Studies in Native Plant Revegetation: Successful Techniques for Severely Disturbed Lands

Patrick Burke

Presentation Summary

The use of native plant species for the restoration and revegetation of disturbed lands has increased dramatically during the past decade. Three case studies of native plant revegetation projects on severely disturbed lands were presented. Special emphasis was placed on the importance of integrating all phases of the revegetation process including planning, implementation, and monitoring. Species selection, seed dormancy, specialized germination requirements, and the importance of utilizing site-adapted genotypes were discussed. The role of appropriate fertilization, mycorrhizal fungi inoculation, and site amelioration techniques were examined within the context of large revegetation projects.

Related Publications

Burke, P. 1991. Ponderosa pine establishment on severely disturbed sites, planning, rehabilitation and treatment of disturbed lands symposium; Billings, MT.

Burke, P. 1994. Woody plant revegetation at Pegasus Gold's Zortman Mine, Wildlife Habitat Enhancement Council, Annual Meeting, Houston, TX.

Burke, P. 1995. New techniques for restoration projects or why restoration is not landscaping. Society for Ecological Restoration, Annual Meeting, Seattle, WA.

Burke, P. 1995. Research needs in restoration horticulture. Society for Ecological Restoration, Annual Meeting, Seattle, WA.

Burke, P. 1996. Native vs. native. Twelfth Biennial High Altitude Revegetation Workshop, Fort Collins, CO.

Burke, P.; Ianson, D. C. 1995. Conceptual plan: final atlas superfund site reclamation. BLM-EPA; Hollister, CA.

Schwartz, E.; Ianson, D. C.; Burke, P.; Zuuring, H. 1995. Atlas Revegetation Pilot Project—1995 biomonitoring report: an evaluation of field management techniques. BLM-EPA; Hollister, CA.

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This symposium was presented on February 18, 1997 during the Society for Range Management 1997 annual meeting in Rapid City, SD. The proceedings contains five papers and three abstracts on issues pertaining to the use of native seeds in wildland revegetation.

Keywords: restoration ecology, germination, plant genetics, rehabilitation, revegetation, seed certification, seed testing, rare plants

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Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.